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Research Report 1686

Using Virtual Environments for Terrain Familiarization: Validation

David M. Johnson and Dennis C. Wightman
U.S. Army Research Institute

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14. ABSTRACT *(Maximum 200 words)*:

Can virtual environment (VE) technology be used to familiarize soldiers with a geospecific location that they have never previously visited: This question was asked in a training validation experiment employing a two-group, preset-posttest design. The domain modeled in the VE was the Hanchey Army Heliport (HAH) located at Fort Rucker. Soldiers in the Hanchey Group explored a virtual model of the HAH, while soldiers in the Control Group explored a virtual model of a section of Arizona. Results showed that the group which explored the virtual Hanchey performed significantly better than the Control Group on all measures of knowledge of HAH. Further, on a transfer test performed at the actual HAH, the Hanchey Group was able to move to unseen locations in a minimum of time with no errors. These results support the proposition that VE technology can be used for terrain familiarization training.

15. SUBJECT TERMS

Virtual environments   Training validation   Simulator research
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Using Virtual Environments for Terrain Familiarization: Validation

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Education and Training Technology

The research discussed in this report was performed by the Simulation Team of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Rotary-Wing Aviation Research Unit at Fort Rucker, Alabama. ARI is committed to enhancing aviation training in the Army. A cornerstone of this commitment is the Simulator Training Research Advanced Testbed for Aviation (STRATA). The STRATA training research objectives are to (1) determine the minimal levels of simulator fidelity required to meet specific task training objectives, (2) define the most effective training strategies for flight simulator technology and training program design to attain and sustain combat readiness for individual tasks and collective training, and (3) delineate the effective ways to train for new operational equipment, tactics, techniques, and procedures based on realistic simulations of battlefield environments.

STRATA has a modular component design so that it can be reconfigured quickly and extensively to emulate a range of training devices--from procedures trainers to full mission simulators. Among STRATA's features are (1) an automated interactive tactical environment, (2) a head- and eye-tracked helmet-mounted display providing for immersion in a computer-generated environment, and (3) the capability to link to Distributed Interactive Simulations (DIS) as a functional node. A proof of concept demonstration of this networking capability was performed on 29 March 1994 when STRATA was linked to five Apache simulators residing in Mesa, Arizona using DIS protocol 2.03.

For the present research, STRATA's flexibility was exploited as a prototype virtual environment training system. Recently, virtual environment technologies have been proposed to provide training in such critical military tasks as premission planning and mission rehearsal. This research represents an attempt to validate empirically the capabilities of virtual environment systems to provide training in external terrain familiarization.

This research was presented to the Department of Defense Training Technology Technical Group at their meeting in Palo Alto, California in May 1994.

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ACKNOWLEDGMENTS

USING VIRTUAL ENVIRONMENTS FOR TERRAIN FAMILIARIZATION:
VALIDATION

EXECUTIVE SUMMARY

Requirement:

   To determine if virtual environment technology can be used to
familiarize soldiers with a geospecific location that they have
never previously visited. Can important terrain information be
transmitted via this medium? Will this information transfer to
the actual, physical location?

Procedure:

   The design was a two-group, pretest-posttest training
validation experiment. The domain modeled in the virtual
environment was the Hanchey Army Heliport (HAH) located at Fort
Rucker, AL. Both groups received pretests and posttests on their
knowledge of the HAH. Between pretest and posttest members of
both groups explored a virtual environment. The Hanchey Group
performed 90 minutes of self-guided exploration of the virtual
HAH, while the Control Group spent an equal period of time
exploring a neutral virtual environment (a section of Arizona).

Findings:

   At pretest the groups did not differ in their knowledge of the
Hanchey Army Heliport. At posttest the group which had explored
the virtual Hanchey knew significantly and substantially more
about the heliport. Upon transfer to the actual HAH, members of
the Hanchey Group were able to navigate in a minimum of time and
without errors from location to location. It was concluded that
virtual environment technology is a valid medium for training
soldiers in terrain familiarization.

Utilization of Findings:

   Research such as this is necessary to establish the validity
of virtual environments for training military tasks where the
geospecific location is crucial--tasks such as premission
planning, mission rehearsal, and special operations. These
results were presented at the 8th Department of Defense Training
Technology Technical Group Meeting at Palo Alto, California in
May, 1994. Given the validation of the basic concept, future
research will examine the effectiveness of virtual environment
technology vis-a-vis other training media.

USING VIRTUAL ENVIRONMENTS FOR TERRAIN FAMILIARIZATION:
VALIDATION

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Introduction

Background

It is commonly acknowledged in the military that everything
except actual combat is simulation. Simulation is generally
meant to refer to one of three classes of activity, either alone
or in combination (e.g., Drabczuk & Tarr, 1993; Singley, 1993).
"Live" simulation is concerned with real equipment in the field.
Field exercises at the National Training Center with soldiers and
vehicles instrumented with the Multiple Integrated Laser
Engagement System are an example of this class of simulation.
"Constructive" simulation refers to wargames, models, and
analytical tools such as Janus and TACWAR. These models
typically run faster than real time on mainframe computers and
are used to simulate large unit operations. "Virtual" simulation
refers to systems and soldiers in simulators fighting on
synthetic battlefields. One example of this class of simulation
is the Simulation Networking (SIMNET) system wherein soldiers in
simulators fight as units in a computer-generated (i.e.,
synthetic) environment. Another example of virtual simulation is
aircraft simulators, which have a relatively long history in the
military (e.g., Hays & Singer, 1989; Wiener & Nagel, 1988).

These three classes of simulation will be linked in the
Army's current approach to simulation design called Distributed
Interactive Simulation or DIS. The official definition of DIS is
reported by Drabczuk and Tarr (1993) as "DIS is a synthetic
environment (at one time described as the 'Electronic
Battlefield') within which humans may interact through
simulations at multiple sites networked using compliant
architecture, modeling, protocols, standards and data bases" (p.
33). Another useful definition is given by Bell, Mastaglio, and
Moses (1993):

> Distributed Interactive Simulation (DIS): The technology of
> linking simulators and workstations representing a diverse
> set of weapons platforms and combat elements over local
> area, wide band, and long haul networks. Linked nodes are
> able to operate within a shared synthetic environment and
> experience common outcomes from combat events. (p. 28)

This report discusses issues and research relevant to the virtual
simulation component of DIS.

Virtual reality and virtual environments. The short history
of virtual reality and virtual environments has already been
amply documented from a number of different perspectives (e.g.,

Aukstakalnis & Blatner, 1992; Ellis, 1991; Krueger, 1991;
Pimentel & Teixeira, 1993; Rheingold, 1991). There is, however,
a certain amount of ambiguity and overlap in the meaning of the
terms "virtual reality" and "virtual environments." Virtual
reality is sometimes defined as the experience of being immersed
in an interactive, three-dimensional, computer-generated
environment (e.g., Pimentel & Teixeira, 1993; U.S. Army Research
Office, 1992). Other times virtual reality is defined as a
computer-generated, interactive, three-dimensional environment in
which a person is immersed (e.g., Aukstakalnis & Blatner, 1992;
Mogal, 1993; Pausch, 1993). The term virtual environment also
refers to a computer-generated, three-dimensional, interactive
environment in which a person is immersed (e.g., Ellis, 1991;
Mowafy & Congdon, 1994; Mowafy & Miller, 1993). The critical
defining features of both terms are computer generation,
immersion in a three-dimensional (3-D) environment, and
interaction. In this report a virtual environment (VE) is
defined as a computer-generated, 3-D environment in which a
person is immersed and with which the person can interact. The
hardware and software which makes this possible is called virtual
environment technology or VE technology.

The experience of immersion was described by Aukstakalnis
and Blatner (1992) this way:

> Being immersed means being surrounded by something;
> everywhere you look, it's there...To create a sense of
> immersion in a virtual environment, we must be able to
> surround ourselves with various stimuli in a manner that
> makes sense and that follows rules similar to those of the
> real world. That is, when you turn your head to the left,
> you see the objects to the left of you. When you walk
> forward, you get closer to the objects in front of you.
> These are elementary features of our sense of being immersed
> in an environment; and when you're in a virtual environment,
> you expect the same results. (p. 27)

The typical mode of immersion is via a head-tracked, head-
mounted (or helmet-mounted) display. Wherever the participant
looks, the computer renders the appropriate view to be seen in
real time or near real time. Sometimes, 3-D sound is provided
through earphones. Sound appears external to the participant and
appears to move with movements of the participant or of the
virtual sound source. The participant can interact with the
virtual environment. Interaction may be limited to locomotion
through the environment (e.g., by joystick or treadmill) or may
include locomotion plus interaction with virtual objects (e.g.,
push virtual buttons, grasp and move virtual objects, doors open
upon proximity, etc.).

Virtual environments in aviation simulation. Aviation
simulation and training technologies are generally recognized as
key intellectual and technical precursors to VE technologies.
The contributions of these earlier aerospace developments to
virtual environments have been discussed by many authors (e.g.,
Aukstakalnis & Blatner, 1992; Ellis, 1991; Moshell, 1993;
Pimentel & Teixeira, 1993; Rheingold, 1991). Critical
technologies such as computer-generated imagery, immersive
widescreen and helmet-mounted displays, and motion cueing were
developed for and continue to be used in commercial and military
aviation simulation and training. The first virtual environment
system was developed in 1982 by U.S. Air Force scientists and
called the Visually Coupled Airborne Systems Simulator or VCASS
(cf. Pimentel & Teixeira, 1993; Rheingold, 1991). VCASS was a
prototype VE cockpit for fighter aircraft. It included a
computer-generated environment based on Department of Defense
digitized terrain databases presented via an immersive, head-
tracked, stereoscopic, fiber-optic, helmet-mounted display.
Targets could be acquired by eye-tracking technology and engaged
by voice command (computer speech recognition) or virtual trigger
pull (tactile glove). Since 1986 scientists at the National
Aeronautics and Space Administration (NASA) Ames Research Center
have been working on the techniques and technology for real time
processing of virtual 3-D acoustic displays (Pimentel & Teixeira,
1993; Wenzel, 1992). The Convolvotron system, now widely used in
VE laboratories worldwide, was developed as a direct result of
this research program.

Besides these purely technical contributions, aviation
simulations themselves can be considered a particular subset of
VE systems (cf. Baum, 1992). Modern, sophisticated, full-mission
aviation simulators immerse their pilots in a computer-generated
environment with which they interact as they would when piloting
the actual, physical aircraft. The Army Research Institute for
the Behavioral and Social Sciences (ARI) owns and operates such a
virtual environment, full-mission, helicopter simulator. This
Simulator Training Research Advanced Testbed for Aviation
(STRATA) is described in the Method section. It utilizes a
helmet-mounted display and a fully functional cockpit to immerse
pilots in a computer-generated environment where they can fly,
fight, and communicate just as they would when performing an
actual mission.

Virtual environments and training. There are many
capabilities inherent to VE technology which may prove valuable
for training. One of these capabilities is the VE itself. Any
environment that can be programmed into a database is capable of
being visualized by the participant. Real world constraints do
not need to apply to these created worlds. For example, virtual
environments exist for the visualization of objects such as
molecules which are normally too small to be seen. Virtual
environments exist for the visualization of objects such as

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galaxies which are normally too large, too dim, and too far away to be seen. Virtual environments also exist to allow the participant to view a new kitchen configuration with new appliances prior to remodeling or to view and walk through an entirely new building before it has been built. Virtual environments even exist which allow for the 3-D visualization of data which are normally seen if at all in 2-D tables or figures-- data such as stock market statistics or weather measurements. Descriptions of these and other applications of VE technology can be found in a number of sources (e.g., Aukstakalnis & Blatner, 1992; Ellis, 1991; Krueger, 1991; Pimentel & Teixeira, 1993; Rheingold, 1991).

An application of this database capability for military training may be to use VE technology to familiarize participants with a location prior to their going to the actual, physical location in person. Thus, virtual environments have been suggested for use in premission planning or mission rehearsal (e.g., Bell, Mastaglio, & Moses, 1993; Landry, 1994; Moshell, Blau, & Dunn-Roberts, 1993; Yuhas, 1993). A likely military mission for which VE training may be a useful form of mission rehearsal would be hostage rescue from a known building by special operations forces. VE technology could be used to familiarize soldiers with the interior of the building prior to the mission. Research relating to this mission has been conducted by Witmer, Bailey, and Knerr (in preparation). The task was to learn a complex route through a building. Participants were trained in one of three groups (i.e., actual building, VE building, and symbolic) and then transferred to the actual building. Participants trained in the actual building performed best on the transfer test, followed by participants trained in the virtual building. The participants trained using symbolic techniques (i.e., written directions, photographs) performed the worst on the transfer test. This experiment provided evidence that participants were able to learn interior route information using VE technology and transfer this knowledge to the actual building.

Another capability of VE that may prove to have training value is the independent control of the observer's viewpoint (also called eyepoint). Many VE systems allow the participant to adopt any viewpoint he or she chooses within the database by means of a joystick or other controlling device. This means that the view the participant receives is not limited to the exigencies of the real world. Participants are free to travel to the top of a mountain that they could never in reality climb, to stop in mid air without falling, or to fly right up to an enemy position without being killed. Moshell (Moshell, 1993; Moshell, Blau, & Dunn-Roberts, 1993) discusses the use of "stealth" platforms in the SIMNET VE. Observers during a virtual replay of the Gulf War battle of 73 Easting control invisible eyepoints (stealth platforms) with which they can adopt any viewpoint on

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the battlefield. They can take a bird's eye view and watch the battle unfold from above. They can observe the battle from the friendly (or hostile) commander's position. They can even hook their viewpoint to one of the players, either friendly or hostile, and tag along wherever that player goes. This stealth capability as it currently exists in the Close Combat Test Bed at Fort Knox is described by Atwood, Winsch, Quinkert, and Heiden (1994). Cosby (1993) speculates how this capability may be used after the turn of the century if present trends continue.

Mowafy and Miller (1993) describe a training program called the Virtual Environment Debrief Interface which employs this capability of variable viewpoint to provide feedback to fighter pilots after flying a simulated air intercept mission. The virtual environment contains the ownship, the target, and their respective flight trajectories portrayed as color-coded streamers. Pilots can view the air intercept replay record from the cockpit of their ownship, the cockpit of the target, or from an external viewpoint. Participants can move around within the VE and view their performance from many external perspectives. Models of expert fighter pilots performing the identical air intercept scenarios are also available to be viewed. The purpose of this training program is to train pilots in the ability to visualize the geometry of an air intercept while the target aircraft is still beyond visual range.

A related, potential advantage of VE technology for training is the inherent three dimensionality of the display medium. Virtual environments offer the possibility of being able to train 3-D tasks directly using a 3-D medium--rather than using 2-D drawings, slides, or standard computer displays. Mowafy and colleagues (Mowafy & Congdon, 1994; Mowafy & Miller, 1993; Mowafy & Thurman, 1993) are exploring this capability in their training programs at the Air Force Armstrong Laboratory. They are using VE technology to provide trainees with an opportunity to learn the spatial relationships of their air combat tasks directly rather than through 2-D transformations of 3-D events. The 3-D Virtual Environment Debrief Interface (VirDI) has been described above (Mowafy & Miller, 1993). An initial experiment investigating the training effectiveness of the VirDI was carried out by Mowafy and Thurman (1993). The VirDI was compared to two other feedback display conditions and to a no feedback control condition. The authors reported a small advantage in air intercept performance favoring the VirDI. Mowafy and Congdon (1994) describe the Virtual Environment Ground Command/Control Training Center. This VE is used to train ground control intercept operators in the tasks necessary to maintain surveillance over the airspace observed by ground-based and airborne radar systems. Participants are able to move throughout this 3-D VE, monitor the activities of all aircraft in real time, and perform basic ground control intercept operator tasks.

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Unlike life in the real world, in a virtual environment everything is known. Everything that is seen or available to be seen is part of the database. In a military application, for example, all platforms are part of the database. They are all known as to type, identity, armaments, location, heading, range, velocity, and status at all points in time. Since the entire virtual world and all events that occur in it are composed of data, some subset of these data can be selected, recorded, analyzed, and presented to the participants in the form of feedback. This is another potential advantage of VE for training. The critical issues are what data would be valuable for training feedback and how best to present them.

The SIMNET Unit Performance Assessment System (UPAS; Meliza, Tan, White, Gross, & McMeel, 1992; Meliza & Tan, in preparation) is an example of such a feedback system for the SIMNET VE. UPAS is a personal computer-based system for use in collecting, analyzing, and presenting SIMNET data to units during after-action reviews. UPAS collects network data on vehicle status and fire events during exercises and loads these data into a relational database at the end of the exercise. UPAS contains menus of graphical and tabular options for the analysis and presentation of performance data. UPAS is designed to be used in addition to the SIMNET replay capabilities to aid the trainer in illustrating key events that lead to exercise outcomes. Instructional features for feedback also exist in a wide variety of nonimmersive simulation systems (cf. Hays & Singer, 1989).

The usefulness of VE technology for training may be dependent upon the task to be trained. It has already been stated above with regard to the work of Mowafy and colleagues that VE technology may be particularly suited to training 3-D, spatial tasks. Regian, Shebilske, and Monk (1992) suggest that VE technology may hold promise for the training of visual-spatial tasks because the VE interface preserves the visual-spatial characteristics of the simulated world. Participants in the Regian et al. experiment were able to use VE technology to learn the spatial configuration of a virtual maze. Unfortunately, however, this experiment did not include a transfer test in an identical real world maze. So the implications of these results for training are not clear.

Kozak, Hancock, Arthur, and Chrysler (1993) found that training performed in a virtual environment did not transfer to a real world perceptual-motor task. There were three groups in this transfer of training experiment--no training, VE training, and real world training. All three groups were transferred to the real world perceptual-motor task. The measure of performance was time to perform the task. The group which received training on the same real world task performed significantly better than the other two groups. The VE trained group did not differ from the group that received no training at all.

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Presence in virtual environments. The sense of being physically present within a computer-generated space--the feeling of actually "being there" when one is immersed in a virtual environment--is called "presence." What are the necessary and sufficient conditions required to create this experience of presence? The popular scientific literature is replete with speculation as to the conditions which cause presence (e.g., Aukstakalnis & Blatner, 1992; Pimentel & Teixeira, 1993; Rheingold, 1991). A listing of these conditions includes: rapid update rate, large field of view, stereoscopic display, high resolution display, eye tracking, head tracking, head-mounted display, 3-D sound, engaging imagery, high image complexity, and interactivity.

The professional scientific community has recognized that before definitive empirical research can be performed to determine the parameters which produce presence, a useful measure of presence must first be devised (e.g., Held & Durlach, 1992; Sheridan, 1992). Responding to this need, two independent groups of ARI scientists have developed instruments designed specifically to measure the reported experience of presence in virtual environments. These are the instruments developed by Psotka and Davison (1993) and by Witmer and Singer (1994). Given valid and reliable measurement instruments, scientific research to explicate the conditions leading to the experience of presence will surely increase.

Research Issues

Military issue. The primary purpose of this experiment was to determine if virtual environment technology can be used to familiarize soldiers with a geospecific location that they have never previously visited. Can important terrain information be transmitted via this medium? Will this information transfer to the actual, physical location? If VE technology is to be used for such critical military tasks as premission planning and mission rehearsal then the answer to the above questions must be yes.

Technology validation issue. Logically, the first issue to be addressed when developing a new technology for training is validation. Will instruction provided by this medium produce an improvement in performance? The minimum research design to address this issue requires two matched groups--a trainee group and a control group. Both groups must be tested before instruction (pretest) to guarantee that they are equally naive to the subject matter prior to instruction. The two groups should not differ at pretest. Both groups must again be tested after instruction (posttest). The trainee group should show a statistically significant improvement in performance from pretest to posttest. The control group, which did not receive the instruction, should not show a statistically significant

improvement from pretest to posttest. More importantly, at posttest the performance of the trainee group should be significantly better than that of the control group. This issue is being investigated in the current experiment.

Once a training technology has been shown to be valid according to the strict standards described above, a second issue arises. This is the issue of the relative effectiveness of the new technology vis-a-vis other technologies. This second issue will be the subject of future research.

Domain. This research required soldiers to use VE technology for terrain familiarization training. This meant choosing some physical location to be modeled in the virtual environment. The domain chosen for virtual familiarization was the Hanchey Army Heliport (HAH) located on Fort Rucker. This heliport was chosen for a number of reasons. First, one potentially valuable application of VE technology to Army Aviation is to familiarize pilots with the physical features and flight pattern information of an airport prior to their arriving there in an aircraft. Second, since the HAH is located at Fort Rucker it is easily accessible for tests of transfer. Third, the HAH is a basing field for the AH-64A Apache helicopter. ARI's STRATA facility at Fort Rucker is currently configured as an Apache helicopter. Hence, the HAH virtual model could have other research uses in the future.

Instructional strategy. The instructional strategy used for familiarization training in this research was self-guided exploration. Soldiers were free to travel about wherever they chose in the VE and to use their own techniques to become familiar with the physical features and flight pattern information present there. This strategy was chosen for two reasons. First, it was an anchor point along the dimension that varied from structured, lockstep, group-based instruction to unstructured, self-guided, individual-based instruction. Second, both past VE training (e.g., SIMNET; Alluisi, 1991) and projected VE training (e.g., DIS; Vaden, 1993) have emphasized free-play learning.

Two group, pretest-posttest, experimental design. Two independent groups of experimentally naive soldiers were run--the Hanchey Group and the Control Group. Members of both groups were pretested on their knowledge of the HAH, then allowed self-guided exploration of the virtual environment, then posttested on their knowledge of the HAH. At the end of the posttest phase all members of both groups rated their experience of presence in the VE on a questionnaire. The independent variable was the information available in the VE. The environment explored by the Hanchey Group was an accurate model of the HAH--which was being tested. The environment explored by the Control Group was a model of a representative portion of the state of Arizona--which

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was neutral for the test.

Hypotheses. Knowledge of the Hanchey Army Heliport: The two groups were not expected to differ significantly in their knowledge of Hanchey at pretest. The Hanchey Group was expected to show significantly more knowledge of the HAH at posttest than the Control Group. The Hanchey Group was expected to improve significantly from pretest to posttest. The Control Group was expected not to improve significantly from pretest to posttest. Presence: The two groups were not expected to differ significantly in their rated presence as a function of which virtual environment they explored.

STRATA. The experiment was conducted using ARI's STRATA. STRATA is a sophisticated research simulation facility designed to address issues pertaining to simulator training effectiveness and the training system complexity needed to accomplish specific training objectives. It is modular and can be reconfigured to represent different training devices with different visual, motion, cockpit, and aeromodel subsystems. For a detailed description of STRATA see Kurts and Gainer (1991). For a description of research conducted to validate STRATA see Stewart (1994). A recent report by Stewart, Wightman, and Gainer (1993) discusses future research planned to be conducted in STRATA. The immediate objective of the research program is to employ STRATA to address four major issues: (a) the minimal level of fidelity required to meet training objectives; (b) the most effective (in terms of outcome and cost) use of flight simulation technology to attain and sustain combat readiness; (c) the most effective ways of defining the use of new operational equipment, tactics, techniques, and procedures in a realistic threat environment; and (d) incorporate lessons learned through STRATA into the development of modular, portable simulation systems.

Method

Participants

Twelve participants were randomly assigned either to the Hanchey Group or to the Control Group. Six were assigned to each group. All participants were soldiers from aviation units at Fort Rucker. All were volunteers and all signed the Volunteer Agreement Affidavit (DA Form 5303-R, May 88). Criteria for selection to this experiment were that participants be soldiers from Fort Rucker who had never visited the Hanchey Army Heliport. Gender, rank, and military occupational specialty were irrelevant for this experiment and were not included as criteria for selection. Table 1 presents a demographic summary of the participants in this experiment.

Table 1

Demographic Description of Experimental Participants[*]

Gender		Rank	
Male:	10	Officers:	4
Female:	2	CPT (2)	
		1LT (1)	
Age (years)		2LT (1)	
Mean:	28.33	Warrant Officers:	5
Median:	27	CW2 (1)	
Range:	23 - 39	WO1 (4)	
		Enlisted:	3
Aviator		CPL (1)	
Yes:	7	PFC (1)	
No:	5	PVT (1)	

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[*] N = 12

Apparatus and Materials

A general description of STRATA. STRATA is currently configured as an AH-64A Apache helicopter. There are two separated cockpits, pilot and copilot-gunner, constructed from salvaged AH-64A cockpits. Both cockpits contain fully functional and integrated flight instruments, sensors, displays, and mission packages. Flight controls are linked between the cockpits. Flight controls produce accurate force feedback. The simulator flies as an Apache due to accurate aerodynamic modeling. Motion cueing is provided to both cockpits by means of hydraulically actuated pneumatic G-seats. The cockpits communicate via intercom. Both cockpits are continuously ventilated with cooled air.

Imagery for both out-the-window views as well as all sensor displays is provided by an Evans and Sutherland ESIG-1000 image generator. This image generator uses eleven channels distributed over three eyepoints (pilot, copilot-gunner, and sensor). There are two infrared post processors for both Apache forward looking infrared radiation (FLIR) sensor displays. Image update rate is 60 Hz.

In the pilot cockpit out-the-window scenes are presented via a fiber optic helmet-mounted display (FOHMD). This display presents four channels of visual information--left and right background and left and right inset (see Figure 1). The

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Individual Background and Inset Fields
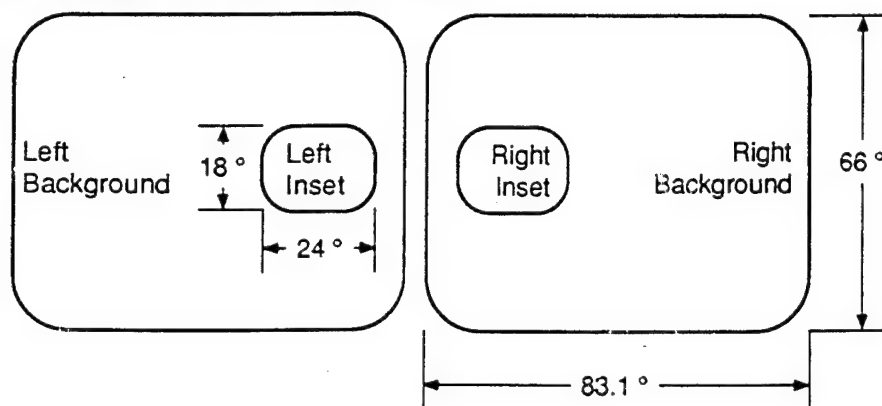
Combined Background and Inset Fields
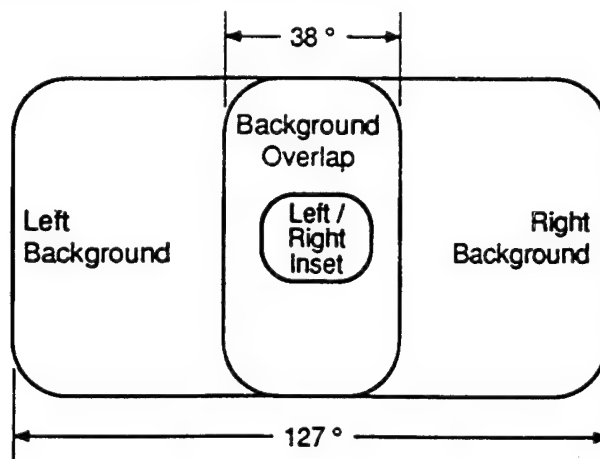
Figure 1. Schematic diagram of the background and inset fields of the fiber optic helmet-mounted display. (The relative scale among the objects is accurate.)

instantaneous background field of view (FOV) is 127 degrees horizontal and 66 degrees vertical. However, since the helmet employs an infrared head tracking system and presents imagery wherever the pilot looks, the effective field of regard is 360 degrees. Infrared eye tracking positions the left and right high resolution insets at the center of the viewer's gaze. These insets subtend 24 degrees horizontal and 18 degrees vertical. Resolution of the background displays is 5.0 arcminutes while resolution of the insets is 1.5 arcminutes. Each left and right background displays 512 lines, 524,000 pixels, and 1200 polygons. Each inset displays 1024 lines, 1,048,000 pixels, and 1200 polygons. Luminance is greater than 35 footlamberts. Contrast ratio is 50 to 1. The FOHMD weighs five pounds but part of this weight is supported by three wires which, though attached to the structure of the simulator, allow full freedom of movement. (The standard Apache flight helmet, the Integrated Helmet and Display Sight Sub-system or IHADSS, also weighs five pounds.) A helmet is custom fitted and optically calibrated to each participant.

All control of the simulator is exercised from the Experimenter-Operator Station (EOS). An experimenter can initiate simulator scenarios, monitor participants in their cockpits, communicate with participants over the intercom, and observe via repeaters the visual scene presented to either cockpit. The Interactive Tactical Environment Management System is used to create scenarios, control multiple intelligent synthetic players (both friendly and hostile), control weapons, terrain, and weather. The Blue-Red Team Station allows the experimenter to control any player in the scenario from the EOS. There is also a Database Management System and Data Recording and Analysis Station, which support tactical scenario generation and performance measurement. A visual database modeling workstation can be used to modify existing visual databases and create new ones.

Experiment-specific features of STRATA. The pilot cockpit was used in this experiment. No flight instruments or flight controls were used. They were covered by a black blanket. Cockpit lights and power were turned off. The G-seat was not used. No vestibular or proprioceptive cues to motion were present in this experiment. Ventilation remained on.

Two joysticks were attached to the seat at a comfortable armchair height--one on the left and one on the right. The left joystick controlled up and down movement. The right joystick controlled forward and backward movement as well as left and right turns. A button on the right joystick was the reset button. Pushing this button caused the image generator to reposition the participant to a particular location in each virtual environment.

The fully-immersive, stereoscopic FOHMD was used for the presentation of all visual information while in the virtual environment. Head tracking was enabled. The combination of the infrared head-tracking system, the rate sensing hardware mounted on the helmet, the prediction algorithms, and a 60 Hz update rate produced a virtual experience with no perceptible head tracking delay. Eye tracking was not used in this experiment. Both the left and the right high resolution insets were fixed forward in the center of the visual field. A helmet was individually fitted and optically aligned for each participant.

During the experiment a large black curtain was drawn completely around the cockpit. This served to prevent ambient light from the dimly lit simulator bay from reaching the cockpit. Once seated in the cockpit the only light was that of the virtual scene displayed by the FOHMD. Participants were completely immersed in the VE and could view the environment by looking in any direction. Participants were not a disembodied eyepoint, however. When looking down participants could see the black virtual carpet on which they were seated. This virtual carpet covered the space immediately under their chair and feet being 2.5 feet wide by 3.0 feet long. It was this virtual carpet which could be made to fly throughout the VE under participant control by manipulation of the left and right joysticks.

During the experiment the four channels of the FOHMD (left and right background, left and right insets) were continuously monitored by the experimenter over four repeater displays at the EOS. The intercom channel was also continuously monitored by the experimenter over earphones at the EOS.

<u>Virtual environments--Hanchey Army Heliport and Arizona</u>. Two virtual environments were used in this experiment--the Hanchey Army Heliport environment and a section of the Arizona environment near the town of Mesa. The HAH environment was created for this and related research. The Arizona environment used in this research was one terrain module taken from the Arizona database. The entire state of Arizona is available in this database and is the baseline database used in STRATA.

The Hanchey Army Heliport virtual environment (HAH-VE) is an accurate, fullscale representation of the actual, physical HAH located on Fort Rucker. The HAH-VE measures 0.72 miles in east-west orientation and 0.52 miles in north-south orientation. The HAH-VE is located in the center of a flat, green, terrain square measuring 40.34 miles on a side. Nothing is visible in the green expanse beyond HAH-VE.

Priority for inclusion in the HAH-VE went to large, permanent or semipermanent, exterior features which identify HAH and to features which are relevant to the flight training mission of the heliport. That is, features were included if they were

exterior, large, relatively permanent, distinctive, or important to the flight mission of the heliport. If features were judged to be critical either for identification, navigation, or flight safety they were included.

Considerable time and effort were expended to acquire the basic physical and flight pattern knowledge required to model Hanchey. Multiple visits to HAH were undertaken by the database modeling and research staff. Subject matter experts were consulted. Defense Mapping Agency data were acquired. Maps were analyzed. U.S. Army Aviation Center (USAAVNC) flight regulations were examined. Measurements were made of all permanent and semipermanent structures at HAH. Videotape and photographic records were made of the entire heliport and all structures both from the ground and from the air.

A two-dimensional, bird's eye view of the largest physical features incorporated in the HAH-VE is presented in Figure 2. Objects presented in this diagram are drawn to scale. This figure is presented with north at the top. The HAH is roughly "T" shaped. The long axis of HAH is oriented generally east-west and is presented left-right in the figure. The shorter axis of Hanchey is oriented generally north-south and is presented top-bottom in the figure. The HAH is situated on a plateau with the ground surrounding the flat tarmac sloping gently away. This is also modeled in the virtual Hanchey where the stem of the "T" (the HAH "panhandle") slopes downhill to the south.

All objects in the virtual Hanchey environment were modeled to actual size and presented in their actual locations. Colors were tuned to match the colors recorded in photographs and on videotape, where feasible. All signs and logos were texture mapped onto buildings in their correct positions.

Among the physical features modeled in the HAH-VE were all nineteen helipads (including one VIP pad), all correctly designated, complete with all aircraft parking ramps, taxi lanes, and overrun areas. All thirty permanent or semipermanent buildings were modeled, including three large hangars, Cobra Hall, Chinook Hall, classroom buildings, storage buildings, the fire station, the operations building, the snack bar, and the guard shack. Critical flight related structures were modeled, including the control tower, the beacon tower, the antenna pole, all three windsocks, and all four fuel tanks. Miscellaneous, distinctive objects were also modeled, including two fire trucks, two natural gas tanks, one water tank, one satellite receiver dish, and all paved automobile parking lots. Some buildings had large, distinctive signs or logos mapped onto them. The Apache hangar had two large Apache logos--one facing east and one west. The Chinook hangar had a large field elevation sign facing east. The Kiowa hangar had a large "Warrior Country" logo and a large field elevation sign both facing south. Chinook Hall had its

Figure 2. Scale diagram of largest physical features present in the Ilanchey Army Heliport virtual environment when viewed from above.
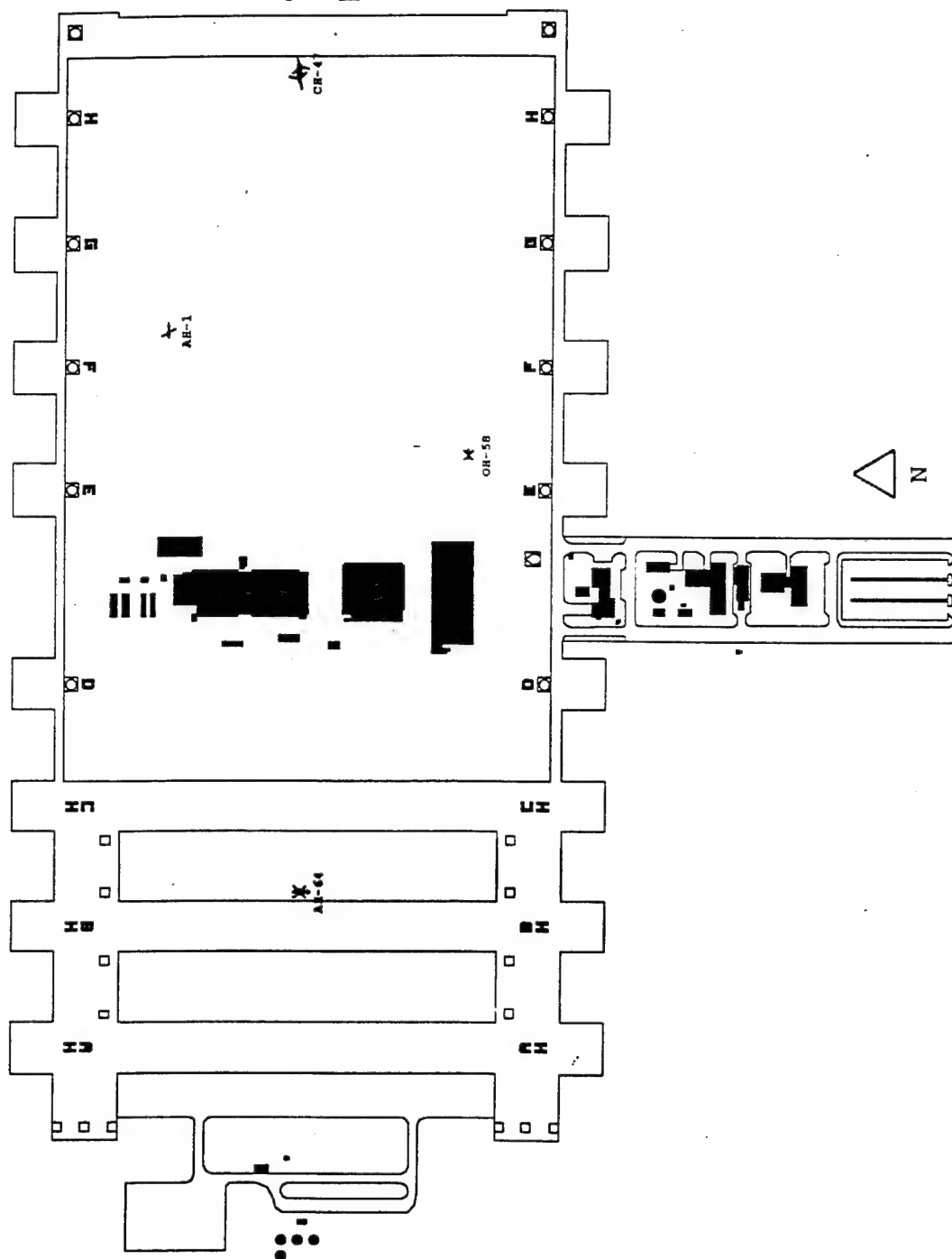
"Chinook Hall Windjammers" logo complete with CH-47 silhouette facing east. Cobra Hall had its large, distinctive "Cobra Hall" logo complete with green cobra snake on a red background facing south.

Included among the physical features of the HAH to be modeled were the helicopters based there. There are four helicopter types based at Hanchey. These are the AH-64 Apache, the AH-1 Cobra, the OH-58 Kiowa, and the CH-47 Chinook. The Apache is based on the west side of HAH, while the other three types are based on the east side. Dozens of these four helicopter types are parked at Hanchey on any given day. The HAH-VE included one exemplar of each of the four helicopter types. All helicopters were parked on their appropriate side of Hanchey and in their correct orientation. The Apache was parked in row B on the west side of HAH-VE in the north-south orientation. The Cobra was parked in row F on the east side of HAH-VE in the east-west orientation. The Kiowa was parked in row E on east HAH-VE in the east-west orientation. The Chinook was parked in row H on east HAH-VE in the east-west orientation.

During the experiment, all four helicopters cycled through their respective traffic patterns in sequence continuously. One by one each helicopter would start its rotor turning, move from its parking place to the taxi lane, taxi to its assigned departure helipad, pick up to a hover, depart along its departure lane and climb to traffic pattern altitude, and then fly the crosswind, downwind, base, and final approach legs of the traffic pattern. Each helicopter would then approach and hover over its assigned landing pad, land, taxi to its assigned parking space, park in the correct orientation, and stop its rotor. At this point another helicopter's rotor would begin to turn and it would perform its traffic pattern flight sequence. This continuous cycle was performed in the order Cobra, Kiowa, Chinook, and Apache. It continued as long as the HAH-VE was enabled.

All phases of the traffic pattern from park through flight back to park were carried out in accordance with USAAVNC flight regulations. All speeds, altitudes, distances, departure lanes, and approach lanes were accurate virtual representations of the actual flight rules followed at the HAH. For example, the traffic pattern altitude for the west Hanchey pattern is 500 feet mean sea level (MSL) but 800 feet MSL for the east Hanchey pattern. The HAH field elevation is 311 feet MSL.

One of the key advantages of VE technology is the capability to make data visible. A salient virtual feature of the HAH-VE was not a physical feature of the actual HAH. A large, red, 3-D compass arrow was always present in the lower center field of view. This arrow pointed to magnetic north and had a white "N" painted on it. This arrow always pointed north no matter how the participant turned the FOHMD or moved the virtual carpet.

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Further, there was no perceptible lag to the directional information provided by the arrow--it kept pace with all helmet or carpet movements no matter how quickly made. Being positioned in the lower center FOV, the arrow provided compass direction without blocking the visual scene.

Figures 3 through 8 present various views of the HAH-VE as photographed from a repeater display in the EOS. Visible in the foreground of all figures is the black, rectangular, virtual carpet and the north-pointing compass arrow. Figure 3 shows a portion of the OH-58 Kiowa hangar. Figure 4 presents Cobra Hall and buildings to the north. Figure 5 displays a portion of the Apache hangar in the foreground with the control tower in the background. Figure 6 shows a parked AH-64 Apache with fuel tanks in the background. Figure 7 displays a parked CH-47 Chinook. Figure 8 presents administrative, storage, and hangar buildings at the north end of the field.
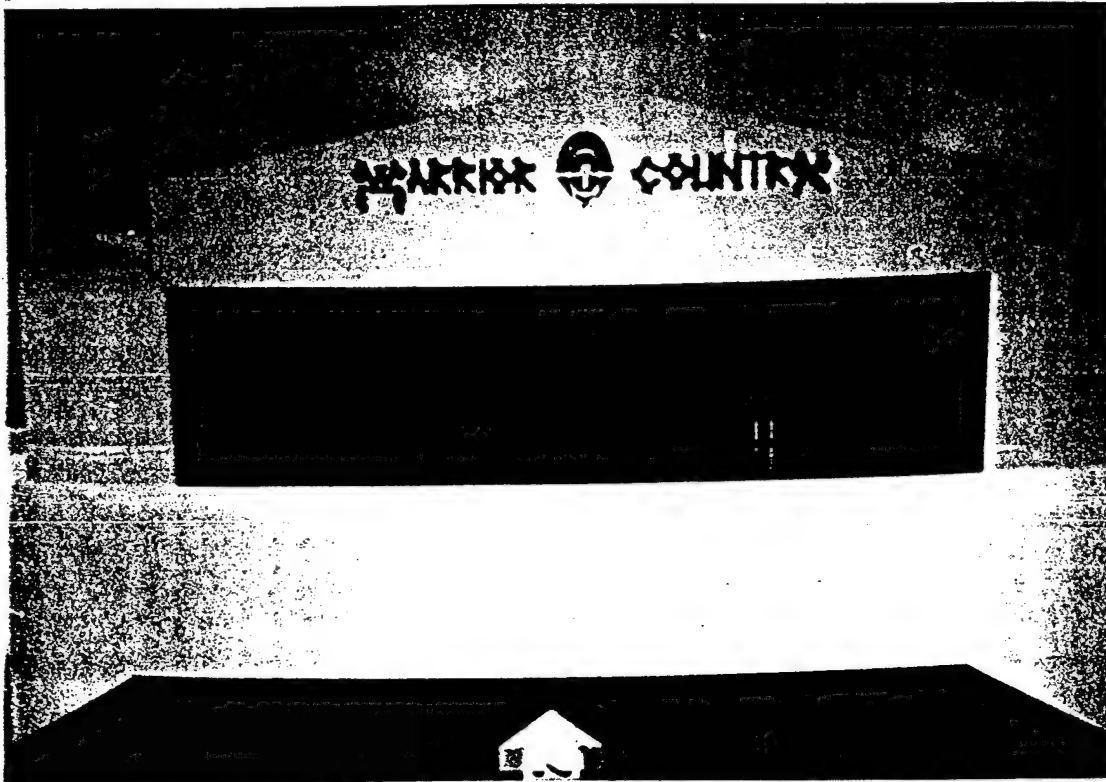
Figure 3. HAH-VE: OH-58 Kiowa hangar.
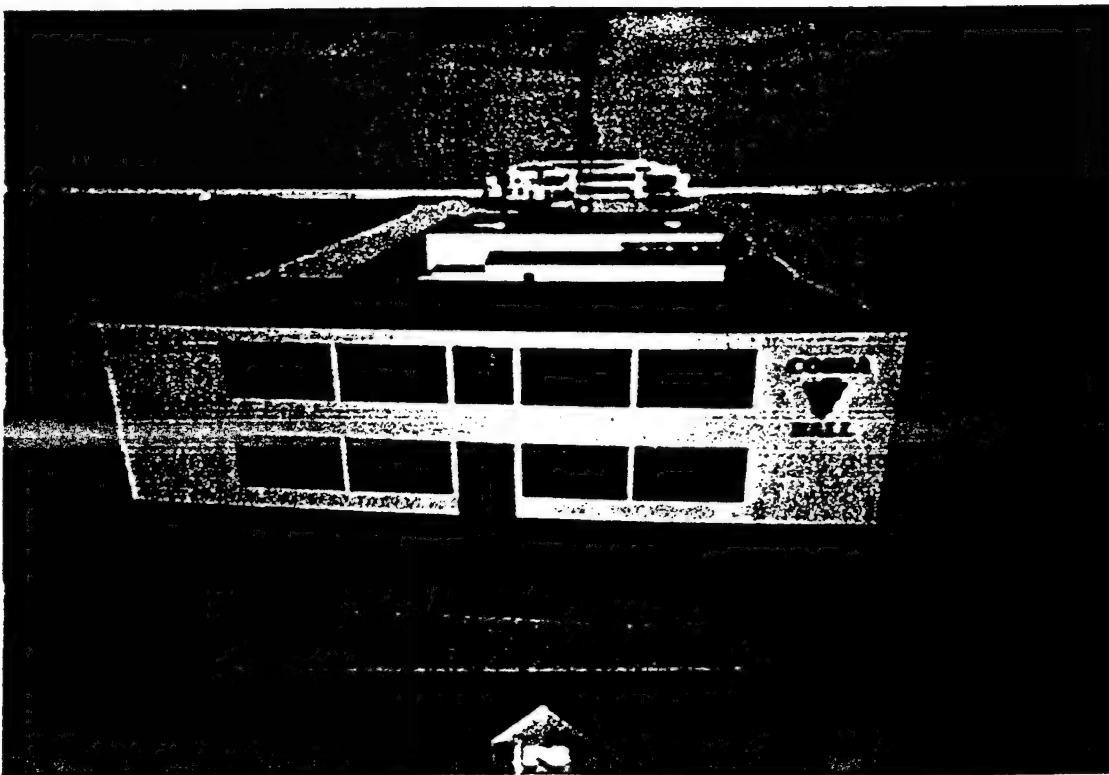
Figure 4. HAH-VE: Cobra Hall and buildings to the north.
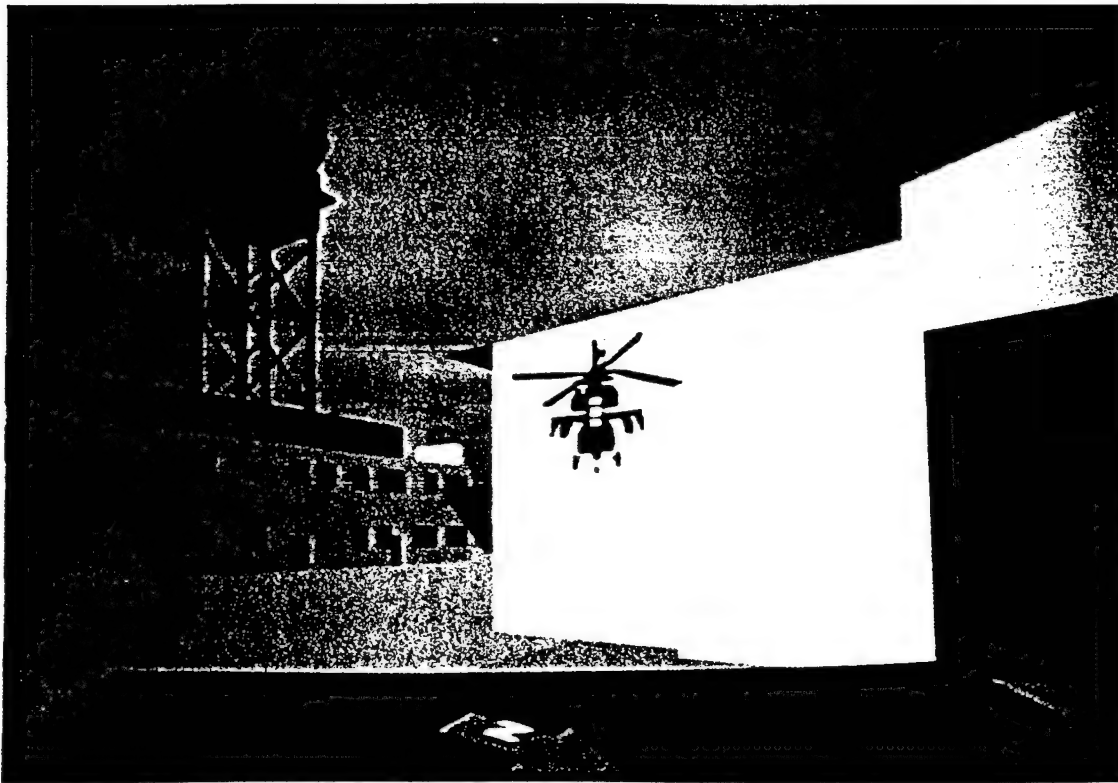
Figure 5. HAH-VE: AH-64 Apache hangar in foreground with control tower in background.

Figure 6. HAH-VE: AH-64 Apache helicopter with fuel tanks in background.

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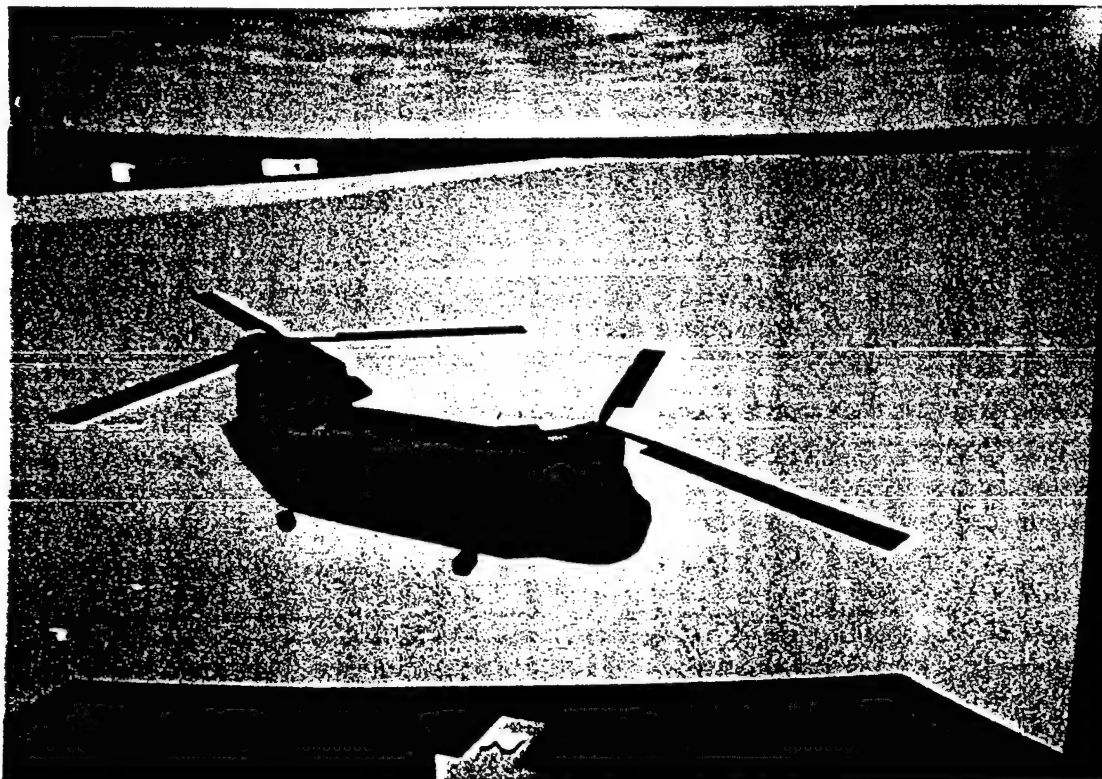
Figure 7. HAH-VE: CH-47 Chinook helicopter.
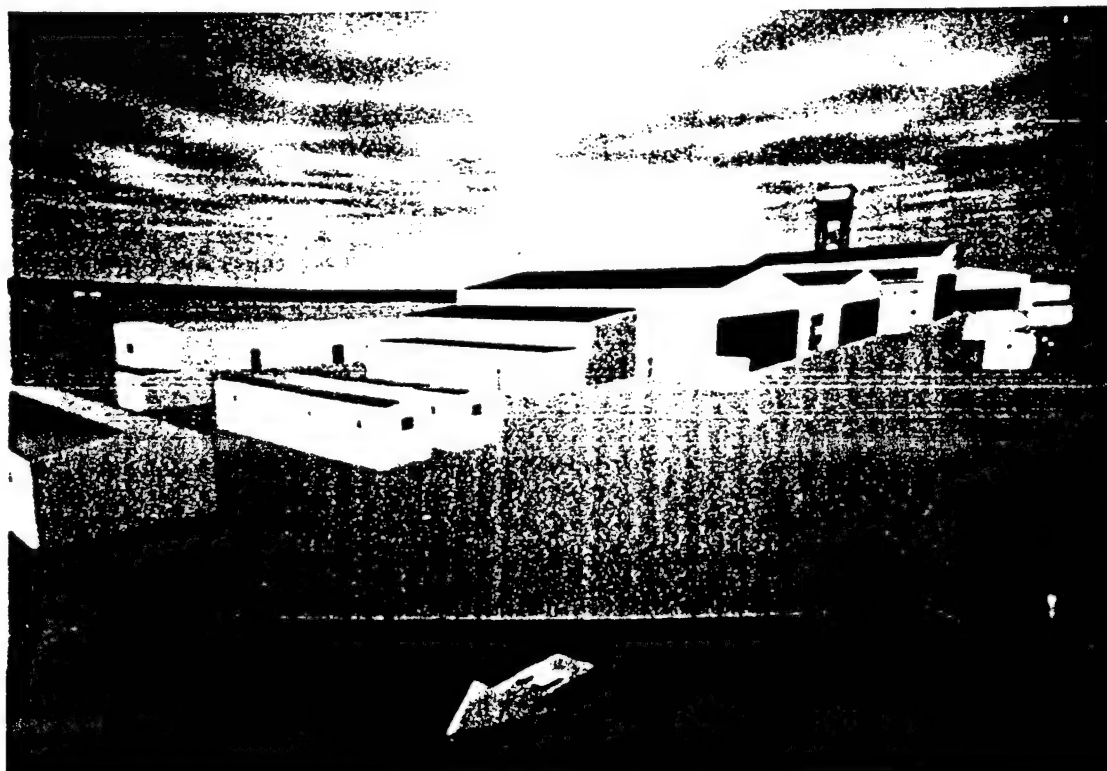
Figure 8. HAH-VE: Buildings at north end of field.

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Pushing the reset button while in the HAH-VE would immediately reposition the participant to a location in front of the southwest section of the OH-58 Kiowa hangar facing north. From this position the participant could clearly see the Warrior Country logo painted on the side of the building. This reset location--including the view of the logo--was the same position from which the Pretest Part 2 and Posttest Part 2 Questionnaires were administered on the visits to the actual HAH during the experiment (see Procedure below).

STRATA did not allow participants to pass underground while in the HAH-VE. Seated on the virtual carpet with the left joystick all the way down, a participant's minimum eyelevel was set at two feet above ground level. A participant had only to look down to see whatever terrain feature was below this eyelevel.

The Arizona virtual environment (Ariz-VE) was located one million feet (189.39 miles) east of the HAH-VE in the same database. The two VEs were separated by empty space and were, of course, not intervisible. Having both the Hanchey and the Arizona environments in the same database meant that participants could be "teleported" from one to the other in a matter of seconds under experimenter control from the EOS.

The Ariz-VE was one terrain module taken from STRATA's Arizona database. This module was a square measuring 10.08 miles on a side. It was centered east of Phoenix and included part of Mesa, Arizona. The Ariz-VE contained urban, residential, and desert terrain. The three terrain types included appropriate types and densities of buildings, businesses, churches, houses, towers, playgrounds, automobiles, roads, parking lots, signs, streams, and vegetation. The Ariz-VE did not contain any aircraft or moving models.

The 3-D, north-pointing compass arrow was also present in the lower center FOV in the Ariz-VE. It functioned exactly the same as it did in the HAH-VE. Pushing the reset button while in the Ariz-VE would immediately reposition the participant to a location in front of a particular gasoline station in the residential terrain. As in the HAH-VE, STRATA did not allow participants to pass underground while in the Ariz-VE. Minimum eyelevel was again set at two feet above ground level.

Forms, questionnaires, and other measures of performance. All participants filled out and signed the Volunteer Agreement Affidavit (DA Form 5303-R, May 88). Information in this form served to identify the participant, the research, the experimenter, the agency, and to guarantee that all participants knew they were participating voluntarily and could withdraw at any time.

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All participants completed and signed the Demographic Information Form (see Appendix). This form served to provide information as to name, social security number, age, rank, unit, telephone number, aviator status, and whether they had ever visited the HAH.

All participants took the Pretest Part 1 Questionnaire (see Appendix). This test consisted of fourteen questions assessing knowledge of HAH. Questions were concerned primarily with flight related physical features of Hanchey. Questions were also asked about the helicopters based at HAH and the flight traffic patterns of east and west Hanchey. Some questions required participants to fill in the correct answers and others were multiple choice. Participants were required to answer each question. Guessing was permitted. Participants who did not know the answer and did not wish to guess were instructed to write "DK" for "don't know." There were eighteen points possible on this pretest.

All participants were administered the Pretest Part 2 Questionnaire (see Appendix). This test consisted of seventeen questions assessing knowledge of HAH. The questions concerned the physical features of Hanchey, the helicopters based there, and the traffic pattern. Some questions covered the same information as in the Pretest Part 1 Questionnaire but in a different format and context. All questions were multiple choice. All questions were asked verbally by the experimenter and all answer options listed. Participants reported their chosen answers verbally. Participants were required to answer all questions. Guessing was permitted. A participant who did not know the correct answer and did not wish to guess could respond "don't know." Don't know was always one of the possible answer options. There were twenty-two points possible on this pretest.

All participants took the Posttest Part 1 Questionnaire (see Appendix). This test was identical to the Pretest Part 1 Questionnaire in every way except its title. It contained the same fourteen questions in the same order. Content, instructions, and scoring were identical to the description given above for the Pretest Part 1 Questionnaire. There were eighteen points possible.

All participants filled out the Posttest Part 1 Object Placement Test (see Appendix). This test assessed participants' knowledge of the physical features of the HAH. It consisted of a generalized diagram of the outlines of the HAH and a list of key objects to be placed in their appropriate locations on the diagram. Objects to be placed were identified with descriptive, uppercase letters. Participants were not required to draw actual features, merely to place the appropriate descriptive letters in the appropriate locations in the diagram. This test was designed

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to measure knowledge of the locations of key Hanchey features, not artistic ability. There were a total of thirty-four objects to be placed correctly in the diagram. Guessing was permitted. If a participant did not know where to place an object and did not wish to guess he or she could leave it blank. An object was scored as being correctly placed if any portion of it was located within 0.25 inch of its correct location. There were thirty-four points possible on this posttest.

All participants were administered the Posttest Part 2 Questionnaire (see Appendix). This test was identical to the Pretest Part 2 Questionnaire in every way except its title. It contained the same seventeen questions in the same order. Content, instructions, and scoring were identical to the description given above for the Pretest Part 2 Questionnaire. There were twenty-two points possible.

The Hanchey Army Heliport Walking Navigation Test was administered only to members of the Hanchey Group (see Appendix). This test measured participants' knowledge of the physical features of the HAH by asking them to use their knowledge to navigate from one location to another in the real world at the actual HAH. This transfer test consisted of two data collection walks. In both, participants began at an initial position and walked to a goal position while passing two waypoints in order along the route. Neither the goals nor the waypoints were visible from the initial positions. Further, to get to the goal locations by passing the two waypoints required following a circuitous route. In addition, neither the goal position nor the waypoints for the second walk were visible during the first walk.

After informing the participant of the goal and the landmarks to pass along the route, the experimenter followed directly behind the participant as he or she walked. Three measures of performance were recorded by the experimenter during each walk: time, in seconds, to walk from start to goal; number of wrong turns taken; and the experimenter's judgement of the participant's confidence level based upon overt behavior. The confidence rating was a three-point scale where 1 meant "unsure, looking, searching, halting steps" and 3 meant "sure, confident, not searching, direct path." A rating of 2 represented a judged level of confidence between 1 and 3.

The Hanchey Army Heliport Knowledge Rating Form was filled out only by members of the Hanchey Group (see Appendix). This form asked each participant to rate the amount of knowledge of Hanchey gained by them in the HAH-VE on a five-point scale. The five rating scale levels were (1) None, (2) Some, (3) Adequate, (4) Much, and (5) Very Much. The levels 1, 3, and 5 were anchored with written descriptions of what the rating meant. These descriptions were included on the form (see Appendix). The purpose of this measure was to get an index of the amount that

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the Hanchey Group participants themselves thought they had learned in the virtual Hanchey environment.

All participants filled out the Presence Questionnaire developed by Witmer and Singer (1994). This questionnaire is presented in the Appendix. Presence was defined by Witmer and Singer as the subjective experience of being in one environment (there) when one is physically in another environment (here). The experience of presence in the VE was measured by this instrument. The questionnaire contained thirty-two questions, each of which required marking an "X" along a seven-point, Likert-type scale. Scoring instructions for this questionnaire as well as evidence of its validity and reliability were provided in Witmer and Singer (1994). Higher scores meant greater reported presence.

Procedure

General. Participation in this experiment required soldiers to be scheduled for two visits to ARI on each of two separate days. Day one activities included helmet fitting and preorientation. This took less than an hour. Day two activities were the experiment proper and included experimental orientation, pretest, exploration of the virtual environment, posttest, Presence Questionnaire, debrief, and question and answer. Day two began when each soldier arrived at ARI at 0700 hours and continued until approximately 1230 hours. One soldier was run in the experiment per day.

Helmet fitting and preorientation. Upon arrival at ARI, participants met with the experimenter (DJ) who checked to make sure that they had never visited the HAH, confirmed the date and time for their participation in the experiment proper, and briefed them in general terms on the nature of the research and what would be required of them. Participants were then fitted for a helmet to support the FOHMD and had the optics calibrated for their eyes. After fitting and calibration each helmet was labelled with the name of the participant and then stored in a recorded location for use during the experiment. At no time during these activities were participants allowed to enter either the simulator bay or the EOS.

Experimental orientation. Upon arrival at ARI on the day of the experiment participants were briefed on the nature of the research, their place in the research, and what was required of them. Questions were answered, where appropriate. Participants were told that there was going to be a pretest followed by self-guided exploration of a VE and then a posttest. Participants were not told that there were two groups (Hanchey, Control) and were not told their group identity. Then participants signed the Volunteer Agreement Affidavit. Participants then completed and

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signed the Demographic Information form. Besides providing the demographic information listed above, this form once again asked them if they had ever visited the HAH. All participants stipulated that they had not.

Pretest. Immediately after the orientation, each participant filled out the Pretest Part 1 Questionnaire at ARI. Then each participant was taken by the experimenter to the HAH located on Fort Rucker. The participant donned opaque goggles, provided by the experimenter, prior to getting within sight of Hanchey. Opaque goggles were worn in order to guarantee experimental control of each participant's visual exposure to HAH. Upon arrival at Hanchey, the participant--still wearing goggles--was lead by the experimenter to a particular location facing the southwest section of the Kiowa hangar. Here the participant was instructed to stand still with head and eyes fixed forward. With the experimenter positioned in front of the participant, the participant removed the goggles. The experimenter read the instructions for the Pretest Part 2 Questionnaire to the participant (see Appendix) and then administered the questionnaire. Participants were instructed to provide verbal responses to the questions read to them from the response options supplied. The experimenter circled each response on the clipboard answer sheet. The experimenter also monitored the participant to guarantee that he or she remained stationary with head and eyes pointed forward during this pretest.

After answering all questions, and while remaining stationary with head and eyes pointed forward, the participant again donned the goggles for the trip back to ARI. Once out of sight of the HAH the participant was allowed to remove the goggles.

Exploration of the virtual environment. Upon return to ARI the participant was taken to the pilot cockpit of STRATA, seated, and given a brief orientation to the simulator. The participant was shown how to adjust cockpit ventilation and where the emergency shut-off switches were located. The participant was shown the FOHMD and how to handle it without touching the optics. The participant was shown the two joysticks and their functions. Last, each participant was shown the air sickness bag. Finally, the participant was helped into the FOHMD and a communication check was made with the experimenter seated at the EOS.

All participants were continuously monitored by the experimenter at the EOS. Experimenter and participant had an open microphone link so that during exploration of the VE the experimenter was always available to the participant. In addition, the experimenter continuously monitored the view seen by the participant in the helmet via the repeaters at the EOS.

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All participants were told that they were to have three exploration sessions of thirty minutes each. They were instructed to learn as much as they could about the VE because they would be asked questions later. They were reminded that they could stop for a break at any time if they wanted a rest, if their helmet developed a "hot spot," or if they began to feel uncomfortable.

Experience in the VE began at the gasoline station reset position in the Ariz-VE for all participants regardless of group. All were instructed to practice controlling their virtual carpet using the two joysticks. After three minutes of joystick control practice in this vicinity, participants were told to return to the initial location by pushing the reset button.

Up until now the procedure was the same for members of both groups. At this point participants who were members of the Control Group were told to begin their first thirty minute exploration session. Participants in the Hanchey Group were teleported from the reset point in the Ariz-VE to the reset point in the HAH-VE by the experimenter at the EOS. They were told to begin their first thirty minute exploration session. Members of the Control Group completed three thirty minute exploration sessions in the Ariz-VE and members of the Hanchey Group completed three thirty minute exploration sessions in the HAH-VE. Sessions were separated by a break of fifteen minutes. During the break each participant was helped off with the FOHMD and got out of the simulator cockpit.

Posttest. Immediately at the end of the third exploration session, the participant completed the Posttest Part 1 Questionnaire. This questionnaire was identical to the Pretest Part 1 Questionnaire except for its title. Next the participant was asked to fill out the Posttest Part 1 Object Placement Test. This posttest had no pretest counterpart. Both of these posttest activities took place at ARI.

Then each participant was again taken by the experimenter to the HAH. The participant again donned opaque goggles prior to getting within sight of Hanchey. Upon arrival at Hanchey, the participant was lead to the same location facing the Kiowa hangar. This was also the same location as the reset point in the HAH-VE. Here the participant was once again instructed to stand still with head and eyes fixed forward. With the experimenter positioned in front of the participant, the participant removed the goggles (which were not used again that day). The experimenter read the instructions for the Posttest Part 2 Questionnaire (see Appendix) and then administered it to the participant. The Posttest Part 2 Questionnaire was identical to the Pretest Part 2 Questionnaire except for its title. The instructions, administration, and scoring procedures were likewise identical to those already described for the pretest

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counterpart.

Up to this point the posttest procedures were the same for members of both groups. At this time participants in the Control Group were transported back to ARI to complete the Presence Questionnaire. Members of the Hanchey Group provided further information as to their knowledge of the HAH.

Members of the Hanchey Group were next administered the Hanchey Army Heliport Walking Navigation Test. This transfer test measured participants' knowledge of the physical features of the HAH gained in the virtual environment by asking them to use this knowledge to navigate from one location to another at the actual HAH. This test consisted of one short practice walk and two walks for data collection.

The experimenter read the instructions for the navigation test (see Appendix) while the participant remained stationary facing the Kiowa hangar. The practice walk required the participant to walk from the initial position at the southwest portion of the Kiowa hangar to the nearest field elevation sign which was located on the southeast portion of the same hangar. The experimenter followed directly behind the participant, with stopwatch and clipboard, recording time in seconds, number of wrong turns, and judged confidence level of the participant. The goal position (field elevation sign) was clearly visible from the initial position and, therefore, this walk did not measure the participant's knowledge of HAH. This practice walk was included to confirm that the participant understood the procedure and to position him/her appropriately for the data collection walk to follow. Experimental data were not collected. None of the goals or waypoints for the following two data collection walks were visible during this practice walk.

The first navigation test walk required the participant to walk from an initial position under the field elevation sign to the two silver natural gas tanks, passing in order two specific landmarks, and using the shortest route without entering any buildings. Neither the goal nor the waypoints were visible from the initial position or from each other. The second navigation test walk required the participant to walk from an initial position at the two silver natural gas tanks to the front of Cobra Hall, passing in order two specific landmarks, and using the shortest route without entering any buildings. Again, neither the goal nor the waypoints were visible from the initial position or from each other. The experimenter followed directly behind the participant recording the three measures of performance during both test walks.

This navigation test was not given to members of the Control Group for a number of reasons. First, it was not considered safe to have a demonstrably naive participant wandering around a busy,

working heliport. ARI agreed to adhere to all heliport safety rules upon requesting access to Hanchey. Second, in an earlier practice test this navigation walk was found to be an impractical measure of performance for members of the Control Group. In order to complete the task an uninformed participant must literally search until he or she has found the goal location and both waypoints and then return to the initial position and perform the task. This can take an inordinate amount of time and produce an impossibly large number of wrong turns. The HAH is a large, complex, detailed area to be searched on foot under the hot Alabama sun. Third, for an uninformed member of the Control Group this navigation walk becomes a search task rather than one of navigation-from-memory. This is a different task than the one ostensibly being measured.

Next, the members of the Hanchey Group filled out the Hanchey Army Heliport Knowledge Rating Form. This form asked each participant to rate the amount of knowledge they gained in the HAH-VE. When finished, participants were transported back to ARI to complete the Presence Questionnaire.

Presence Questionnaire, debrief, question and answer. Upon their return to ARI all participants completed the Presence Questionnaire. After finishing the questionnaire each participant was fully debriefed as to the nature of the research, the experimental design, his/her role and group membership, and any questions were answered. After releasing the participant the goggles were cleaned with isopropyl alcohol in preparation for the next day's experiment.

Results

Scoring

Objective keys and reliable scoring procedures were created for the five instruments which measured knowledge of HAH. These instruments were: Pretest Part 1 Questionnaire, Pretest Part 2 Questionnaire, Posttest Part 1 Questionnaire, Posttest Part 1 Object Placement Test, and Posttest Part 2 Questionnaire. Responses recorded on these instruments were scored individually by both authors (DJ, DW). Scorer DJ, being the experimenter, was aware of which group (Hanchey or Control) each participant was a member of during scoring. Scorer DW was blind as to the group membership of participants. As shown in Table 2 interscorer reliability was almost perfect. Scores used in later analyses were those of DJ.

Table 2

Interscorer Reliability of Scorers DJ and DW

Instrument	Correlation*
Pretest Part 1 Questionnaire	r = 1.00, df = 10, p<.001
Pretest Part 2 Questionnaire	r = .99, df = 10, p<.001
Posttest Part 1 Questionnaire	r = 1.00, df = 10, p<.001
Posttest Part 1 Object Placement	r = .99, df = 10, p<.001
Posttest Part 2 Questionnaire	r = 1.00, df = 10, p<.001

*Pearson Product-Moment Correlation Coefficient

The Presence Questionnaire was scored in the manner described by Witmer and Singer (1994). Participants placed an "X" in one of seven bins along a seven-point, Likert-type scale. For twenty-five of the thirty-two questions the left-most bin was scored a rating of 1 and the right-most bin a rating of 7. Seven questions were reverse scored, with the left-most bin scored as a rating of 7 and the right-most bin scored as a rating of 1. The questions which were reverse scored were numbered 8, 9, 11, 24, 25, 28, and 29. The total score for each participant was the sum of the ratings from all thirty-two questions. The Presence Questionnaire was scored by DJ.

Analyses

Knowledge of Hanchey Army Heliport. The purpose of this experiment was to determine if knowledge about an actual location could be transmitted via VE technology. The experiment was a simple pretest-posttest design with two independent groups. The Hanchey Group explored a VE representation of the tested location (HAH) while the Control Group explored a VE representation of a neutral location (Arizona). Therefore, two classes of planned, pairwise comparisons were run. First, comparisons between the Hanchey Group and Control Group on all pretest and posttest measures. These comparisons employed a series of independent groups t-tests. All pretest comparisons were two-tailed tests. No significant differences in either direction were predicted. All posttest comparisons were one-tailed tests. Differences were predicted to favor the Hanchey Group. Second, comparisons were made between pretest performance and posttest performance for all repeated measures for both groups. These comparisons employed a series of repeated measures t-tests. All pretest versus posttest comparisons were one-tailed tests. Differences were predicted to favor the posttest.

Presence. A secondary purpose of this research was to measure the experience of presence reported by participants in the VEs. It was of interest to learn if there would be a difference in reported presence between the Hanchey and Control Groups. The two groups explored VEs which differed only in content. Therefore, the total presence score was compared between groups. This planned, pairwise comparison was analyzed using a Mann-Whitney U test in addition to the independent groups t-test. The nonparametric U test was added because the Presence Questionnaire produced ordinal-level data (but see Gaito, 1980). Both presence comparisons were two-tailed tests. No significant differences in either direction were predicted.

Knowledge of Hanchey Army Heliport

Hanchey Group versus Control Group. The mean scores (and percent correct) of the Hanchey Group and the Control Group on the five instruments measuring knowledge of HAH are presented in Table 3. The two pretest instruments were administered to all participants prior to their experience in the VE. The three posttest instruments were administered to all participants after their experience in the VE. The numbers in the table represent the mean and standard deviation of correct answers on the measurement instruments by group. On the Pretest Part 1 Questionnaire the Hanchey Group mean score was 1.00 out of a possible 18, while that for the Control Group was 0.50. There was no statistically significant difference between the groups on this questionnaire ($t(10) = 0.70$, $p>.10$, 2-tailed). On the Pretest Part 2 Questionnaire both groups scored 1.00 out of a possible 22. There was no statistically significant difference between the groups on this questionnaire ($t(10) = 0.00$, $p>.10$, 2-tailed). The results showed no statistically significant differences between the groups at pretest in their knowledge of HAH.

The Hanchey Group scored 16.83 out of a possible 18 on the Posttest Part 1 Questionnaire, while the Control Group scored 0.67. This difference was statistically significant ($t(10) = 20.78$, $p<.001$, 1-tailed). On the Posttest Part 1 Object Placement Test the Hanchey Group scored 27.50 out of a possible 34, while the Control Group scored 0.83. This difference was statistically significant ($t(10) = 7.55$, $p<.001$, 1-tailed). The Hanchey Group scored 20.67 out of a possible 22 on the Posttest Part 2 Questionnaire, while the Control Group scored 1.67. This difference was statistically significant ($t(10) = 12.38$, $p<.001$, 1-tailed). The results consistently showed statistically significant differences between the groups at posttest in their knowledge of HAH.

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Table 3

Comparison of Scores (and Percent Correct) of Hanchey Group and
Control Group on Instruments Measuring Knowledge of Hanchey Army
Heliport Before and After Experience in the Virtual Environment

Instrument	Hanchey[*]	Control[*]
Pretest Part 1 Questionnaire		
Mean	1.00 (6%)	0.50 (3%)
SD	1.41	0.76
Pretest Part 2 Questionnaire		
Mean	1.00 (5%)	1.00 (5%)
SD	1.41	1.41
Posttest Part 1 Questionnaire[**]		
Mean	16.83 (94%)	0.67 (4%)
SD	1.34	1.11
Posttest Part 1 Object Placement[**]		
Mean	27.50 (81%)	0.83 (2%)
SD	7.76	1.46
Posttest Part 2 Questionnaire[**]		
Mean	20.67 (94%)	1.67 (8%)
SD	2.98	1.70

[*] N = 6 each group
[**] Hanchey Group versus Control Group: $p < .001$

Pretest versus posttest. The Part 1 Questionnaire and Part
2 Questionnaire were administered both before exploration of the
VE (pretest) and after this exploration (posttest). The mean
pretest and posttest scores (and percent correct) on these two
questionnaires are presented in Table 4 by group. The Hanchey
Group scored 1.00 on the Part 1 Questionnaire at pretest and
16.83 at posttest. This improvement was statistically
significant (t(5) = 19.98, $p < .001$, 1-tailed). On the Part 2
Questionnaire the Hanchey Group scored 1.00 at pretest and 20.67
at posttest. This improvement was also statistically significant
(t(5) = 13.33, $p < .001$, 1-tailed). The results showed
statistically significant improvement from pretest to posttest on
both repeated measures of knowledge for the Hanchey Group.

The Control Group showed a different pattern of results. On
the Part 1 Questionnaire the Control Group scored 0.50 at pretest
and 0.67 at posttest out of a total possible score of 18. There

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was no statistically significant difference for the Control Group between pretest and posttest performance on the Part 1 Questionnaire ($\underline{t}(5) = 1.00$, $\underline{p}>.10$, 1-tailed). On the Part 2 Questionnaire the Control Group scored 1.00 at pretest and 1.67 at posttest out of a total possible score of 22. There was no statistically significant difference between pretest and posttest performance for the Part 2 Questionnaire ($\underline{t}(5) = 2.00$, $.10>\underline{p}>.05$, 1-tailed). The results consistently showed no statistically significant improvement from pretest to posttest for the Control Group.

Table 4

Comparison of Pretest versus Posttest Scores (and Percent Correct) on Instruments Measuring Knowledge of Hanchey Army Heliport for Both Groups

Group[*]	Pretest	Posttest
Hanchey		
Part 1 Questionnaire[**]		
Mean	1.00 (6%)	16.83 (94%)
SD	1.41	1.34
Part 2 Questionnaire[**]		
Mean	1.00 (5%)	20.67 (94%)
SD	1.41	2.98
Control		
Part 1 Questionnaire		
Mean	0.50 (3%)	0.67 (4%)
SD	0.76	1.11
Part 2 Questionnaire		
Mean	1.00 (5%)	1.67 (8%)
SD	1.41	1.70

[*] $\underline{N} = 6$ each group
[**] Pretest versus posttest: $\underline{p}<.001$

Other measures. In addition to the instruments reported above, the Hanchey Group provided two other measures of their knowledge of HAH during the posttest phase of the experiment. First, they participated in the Hanchey Army Heliport Walking Navigation Test. Then they rated the amount of knowledge they thought they had gained in their exploration of the HAH-VE on the Hanchey Army Heliport Knowledge Rating Form.

The Walking Navigation Test measured the time taken, the number of wrong turns made, and the judged confidence level of each participant while performing two self-guided navigation trials on the actual HAH. In the first test trial the mean time taken to walk from initial location to goal location was 315.50 seconds. No participant made any wrong turns (mean = 0). All participants were judged to have a confidence level of 3 or "sure" (mean = 3). By comparison, the experimenter (DJ) who designed the walking test and was intimately familiar with the route from actual experience required 335 seconds to walk the test route during a preexperimental calibration trial. Four of the six Hanchey Group participants walked the route in less time than the experimenter, based only on their knowledge of HAH acquired in the VE.

In the second test trial the mean time taken by the Hanchey Group participants was 475.33 seconds. Again, no participant made any wrong turns (mean = 0) and all participants were judged to have a confidence level of 3 or "sure" (mean = 3). Again, by comparison, the experimenter who designed the test required 490 seconds to walk the route during a preexperimental calibration trial. Three of the six participants completed this trial route in less time than the experimenter, based only on their knowlege of HAH acquired in the VE.

All members of the Hanchey Group filled out the HAH Knowledge Rating Form which required them to rate the amount of knowledge they had gained in the VE. Five of the six participants rated their knowledge gained as 5 ("Very Much") and one rated his at 4 ("Much") for a mean group rating of 4.83.

Presence Questionnaire

All participants were administered the Presence Questionnaire in order to assess their degree of psychological immersion or presence in the virtual environment they explored. Presence Questionnaire ratings are presented in Table 5 for each group separately and for both groups combined. There was no statistically significant difference between the Hanchey Group and the Control Group in presence ratings ($t(10) = 1.08$, $p>.10$, 2-tailed; Mann-Whitney $U(6,6) = 12$, $p>.10$, 2-tailed). The mean presence rating for both groups combined was 157.75.

Table 5

Mean Presence Questionnaire Ratings for Hanchey Group, Control
Group, and Combined

	Hanchey Group*	Control Group*
Mean	154.83	160.67
SD	7.62	9.37
N	6	6

	Both Groups Combined
Mean	157.75
SD	9.03
N	12

* Hanchey Group versus Control Group: p>.10

Simulator Sickness

Because simulator sickness was not a research issue under
investigation in this experiment, it was not systematically
measured for all participants. Thirteen soldiers were originally
scheduled for participation in this experiment. Two participants
experienced simulator sickness and were requested to fill out the
Simulator Sickness Questionnaire (SSQ) of Kennedy, Lane, Berbaum,
and Lilienthal (1993). One of the two participants reported
sickness of sufficient severity to cause him to request
withdrawal from the experiment. This participant did not vomit
but did report on the SSQ moderate or severe symptoms of:
general discomfort, fatigue, headache, eyestrain, nausea,
fullness of head, blurred vision, dizziness, vertigo, and stomach
awareness. These symptoms all occurred within the first fifteen
minutes of experience in the virtual environment. This
participant had been assigned to the Hanchey Group and was
exploring the virtual Hanchey. As for predisposing factors, this
participant reported many fewer hours of sleep than usual the
night prior to the experiment. This participant was excused from
the experiment and his data were not included in the results of
this report.

The other participant vomited into his air sickness bag
eight minutes into his third session in the VE (68 minutes into
the 90 minute total session length). This participant had not
reported any symptoms over the intercom prior to his sickness.
He expressed surprise that the sickness had come upon him so
suddenly. He reported moderate symptoms of dizziness and stomach
awareness on the SSQ. This participant had been assigned to the

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Control Group and was exploring the virtual Arizona. As for predisposing factors, he had received many fewer hours of sleep than usual the three nights prior to the experiment because of his Army duties. This participant did not request withdrawal from the experiment and in fact reported he felt fine after the vomiting episode. After a 25 minute break during which he filled out the SSQ, this participant returned to the Ariz-VE and finished the experiment. His data were included among those in the Control Group.

Discussion

The primary purpose of this experiment was to determine if VE technology can be used to familiarize participants with a place prior to their going there. That is, can important terrain information be transmitted via this medium and will this information transfer to the actual physical location? Another purpose was to measure the presence reported by participants in each of the two virtual environments--the HAH-VE for the Hanchey Group and the Ariz-VE for the Control Group.

Knowledge of Hanchey Army Heliport

A variety of converging measurements support the conclusion that the participants in this experiment were able to learn terrain knowledge of the HAH using VE technology and were able to transfer this information to the actual heliport. One of the selection criteria for this experiment was that participants had never visited the HAH. All participants signed a form stating that they had not. This lack of knowledge of HAH was amply demonstrated at pretest by both the Hanchey Group and the Control Group (see Table 3). On the Pretest Part 1 Questionnaire administered at ARI both groups scored near zero in their knowledge of HAH (6%, 3%). On the Pretest Part 2 Questionnaire administered at Hanchey both the Hanchey Group and the Control Group again scored near zero in their knowledge of HAH (5%, 5%). There were no statistically significant differences between the groups in their knowledge of HAH at pretest.

After exploration of their respective virtual environments the situation was dramatically different (see Table 3). The Control Group, which had been exploring the neutral Ariz-VE, continued to score near zero on both the Posttest Part 1 Questionnaire (4%) and the Posttest Part 2 Questionnaire (8%). The Control Group did not show a statistically significant improvement from pretest to posttest on either questionnaire (see Table 4). In addition, the Control Group scored near zero on the Posttest Part 1 Object Placement Test (2%; see Table 3) which was a posttest measure only.

The Hanchey Group, however, had been exploring the HAH-VE and had learned a good deal. At posttest the Hanchey Group scored near perfect on both the Posttest Part 1 Questionnaire and the Posttest Part 2 Questionnaire (94%, 94%; see Table 3). The Hanchey Group showed statistically significant improvement from pretest to posttest on both questionnaires (see Table 4). In addition, the Hanchey Group scored 81 percent correct on the Posttest Part 1 Object Placement Test (see Table 3). At posttest the Hanchey Group scored significantly and substantially better than the Control Group on all three measures of knowledge where the two groups were compared directly (see Table 3).

Clearly, the results of this experiment show that participants were able to gain knowledge of the actual HAH from the virtual HAH. On tests of knowledge administered both at ARI and at HAH participants in the Hanchey Group went from scores near zero to scores near perfect after ninety minutes of exploration in the virtual Hanchey. On these same tests members of the Control Group scored near zero at pretest and showed no improvement at posttest. The existence of the Control Group in this experiment means that the improvement seen by the Hanchey Group cannot have been caused by differences at pretest, by repeated knowledge testing, by exploration of just any virtual environment, or by the mere passage of time. The only parsimonious explanation of these results is that the Hanchey Group learned about the HAH during their exploration of the virtual Hanchey. That is, external terrain knowledge can be transmitted by means of VE technology.

Not only were the Hanchey Group participants able to learn about Hanchey from the virtual environment but they were able to transfer this knowledge to the actual site. All members of the Hanchey Group executed two trials of the HAH Walking Navigation Test immediately after the questionnaire portion of the posttest. On two different trials of this test participants were asked to find their way from an initial starting point to a goal point using the shortest possible route without passing through buildings. On their way from start to goal they were to pass two landmarks in order. Neither the goal points nor the en route landmarks were visible from the starting points or from each other. Neither the goal nor the waypoints for trial number two were visible during trial number one. Further, the correct route on each trial was a circuitous one. In other words, this task could not be performed quickly, confidently, and without error either by chance or by visual search. To perform this task perfectly--which they all did--participants were required to have developed some sort of detailed mental representation of HAH while exploring the VE and be able to apply this knowledge to navigating the actual site.

The results showed that all participants exuded confidence as they performed both trials with zero wrong turns and with no wasted time spent deciding or searching. The mean times to reach the goal points were lower for the members of the Hanchey Group than were those times recorded for the experimenter who not only designed the test routes but who was intimately familiar with both the virtual and the physical HAH. Some participants walked the routes so rapidly, in fact, that the (older) experimenter--following with his stopwatch and clipboard--had to admonish them to slow down so he could keep up. The participants showed no difficulty whatsoever transferring the knowledge gained in the virtual environment to the navigation task in the actual environment.

These objective measures of performance were consistent with the self reports of the Hanchey Group participants. At the end of the posttest, while still at HAH, participants were given an opportunity to rate the amount they learned in the HAH-VE on a five-point scale. The mean self rating was 4.83 or "Very Much." The anchoring description provided for this rating was: "I learned a great deal in the virtual environment. I feel highly knowledgeable about Hanchey now." Consistent with their posttest performance participants believed they had learned a substantial amount from their exploration of the virtual Hanchey.

In summary, this research has employed three types of measures to investigate whether virtual environment technology can be used to provide terrain familiarization training to soldiers. The three measurement types were: questionnaire-based tests of knowledge administered both at the actual terrain location and at a remote location; performance-based navigation tests conducted at the actual terrain location; and self reports of amount learned. All measures consistently showed high levels of learning. There does not appear much room for doubt that terrain information can be transmitted via virtual environment technology. Whether this technology is efficient or cost-effective relative to other media used for such training is a subject for further research.

Presence

All participants rated the amount of presence they experienced using the questionnaire developed by Witmer and Singer (1994). There was no statistically significant difference in rated presence between the Hanchey Group and the Control Group (see Table 5). This is an understandable result since the only difference between the virtual experiences provided the two groups was the content of the virtual environments. The Hanchey Group explored the HAH-VE while the Control Group explored a section of the Ariz-VE. Even these different locations were similar in general ways. For example, both environments contained a similar density of artifacts (buildings, towers,

roads) and both contained the visible, virtual compass arrow. All the equipment used to present the virtual experience was identical for both groups. The helmet and headtracking technology was identical. The movement control via left and right joysticks was identical. The sole difference was, again, the location modeled in the VE. Under such stable conditions as these one would be surprised--even suspicious--if significant differences in rated presence did emerge.

The mean presence score in this experiment of 157.75 (SD = 9.03, N = 12) was reasonably consistent with other reported scores using the same questionnaire, once differences in experimental method were taken into consideration. Witmer, Bailey, and Knerr (in preparation) reported a mean presence score of 147.25 (SD = 15.20, N = 20). Their experiment employed a different category of participants (college students) and a different experimental apparatus. The experimental task, however, was similar. Participants used the VE technology to learn a complicated route through the interior of a building and then transferred this knowledge to a test in the actual building.

Witmer and Singer (1994) reported a mean presence score of 144.29 (SD = 16.68, N = 16) for the first administration to their sample and 138.29 (SD = 23.32, N = 16) for the second administration. Their experiment also employed college students and a different experimental apparatus. In addition, the task was quite different. Participants performed a series of perceptual and psychomotor tasks in a predetermined order within the VE. Given these differences in method, differences in rated presence would not be unexpected.

Research to determine the impact of different participants, equipment, and procedures on rated presence will require dedicated experiments which manipulate these independent variables directly and measure presence within the same design. Given the variability noted above in the presence ratings (see SDs) within-subjects rather than independent-groups designs would probably be preferable wherever possible.

Conclusion

Soldiers were able to learn external terrain information from self-guided exploration of a virtual environment and transfer this knowledge to the actual, physical environment that had been modeled. The existence of the Control Group in this experiment rules out possible alternative explanations for the improvement in performance seen by the soldiers trained in the virtual environment. Thus, under the criteria discussed earlier in this report, virtual environment technology has been shown to be a valid medium for the transmission of terrain knowledge.

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APPENDIX

Forms, questionnaires, and other measures of performance

Date_____   #_____

FAMILIARIZATION WITH VIRTUAL ENVIRONMENTS

Demographic Information Form

All information you provide will be used for research purposes only. Your anonymity is assured.

1. Name: _____
                 Last   First   Middle

2. Social Security No.: __ __ __ - __ __ - __ __ __ __

3. What is your age? _____ Years

4. What is your current rank? _____

5. To which unit are you assigned? _____

6. Daytime Telephone Number(s): _____

7. Are you an aviator? _____

8. Have you ever visited Hanchey Army Heliport? _____

_____
     Your Signature

Familiarization with Virtual Environments

Pretest Part 1 Questionnaire

Please answer all questions. Circle the correct answer where
appropriate. Guessing is permitted. If you do not know what the
answer is and do not wish to guess, write "DK" for don't know.

1. Which helicopter type (types) is (are) based on the West ramp
at Hanchey Army Heliport?

2. Which helicopter type (types) is (are) based on the East ramp
at Hanchey Army Heliport?

3. In which compass orientation are the helicopters parked on
the West ramp at Hanchey? North-South orientation or East-West
orientation?

4. In which compass orientation are the helicopters parked on
the East ramp at Hanchey? North-South orientation or East-West
orientation?

5. How many helipads are located on the West ramp of Hanchey?

6. How are these helipads identified or designated? (That is,
list the identification or designation of each of these
helipads.)

7. Which traffic pattern is at a higher altitude? West Hanchey
traffic pattern or East Hanchey traffic pattern?

8. How many windsocks are located at Hanchey?

9.   Where is (are) the windsock(s) located relative the control
tower?   Use compass direction (i.e., North, South, East, West) to
locate each windsock.

10.   Where is the beacon tower located relative to the control
tower?   North, South, East, or West?

11.   Where is the fire station located relative to the control
tower?   North, South, East, or West?

12.   Where are the fuel tanks located relative to the control
tower?   North, South, East, or West?

13.   How many fuel tanks are there?

14.   What is the field elevation of Hanchey in feet?

Familiarization with Virtual Environments

Pretest Part 2 Questionnaire

I am going to remove your goggles. Hold your head and eyes
steady and pointed forward. Do not turn your head to the left or
the right. Do not move from this spot. I am going to ask you
some questions. Please answer all questions. Guessing is
permitted. If you do not know an answer and do not wish to
guess, say "don't know."

a.   Do you see the "Warrior Country" logo?   Yes   No

1.   Where is the control tower located relative to your position?
To your front, back, left, or right?   DK

2.   Where is the fire station located relative to your position?
To your front, back, left, or right?   DK

3.   Which helicopter type or types are parked to your left?
AH-64 Apache   AH-1 Cobra   CH-47 Chinook   OH-58 Kiowa
UH-60 Blackhawk   UH-1 Huey   TH-67 Creek   RAH-66 Comanche
DK

4.   Which helicopter type or types are parked to your right?
AH-64 Apache   AH-1 Cobra   CH-47 Chinook   OH-58 Kiowa
UH-60 Blackhawk   UH-1 Huey   TH-67 Creek   RAH-66 Comanche
DK

5.   Where is Cobra Hall relative to your position?   To your
front, back, left, or right?   DK

6.   Where is the beacon tower relative to your position?   To your
front, back, left, or right?   DK

7.   Where is the antenna pole relative to your position?   To your
front, back, left, or right?   DK

8.   Where are the fuel tanks relative to your position?   To your front, back, left, or right?   DK

9.   Where is the water tank relative to your position?   To your front, back, left, or right?   DK

10.   Where is the nearest "field elevation" sign to your position?   To your front, back, left, or right?   DK

11.   Where is taxi lane Delta relative to your position?   To your front, back, left, or right?   DK

12.   Where is taxi lane Echo relative to your position?   To your front, back, left, or right?   DK

13.   Which aircraft traffic pattern is at a higher altitude, the traffic pattern to your left or the traffic pattern to your right?   Left   Right   DK

14.   Relative to your position, is there a windsock:
      To your front?   Yes   No   DK
      To your back?   Yes   No   DK
      To your left?   Yes   No   DK
      To your right?   Yes   No   DK

15.   Where is Windjammers Chinook Hall relative to your position? To your front, back, left, or right?   DK

16.   Where are the two silver natural gas tanks relative to your position?   To your front, back, left, or right?   DK

17.   Where is the satellite receiver dish relative to your position?   To your front, back, left, or right?   DK

Familiarization with Virtual Environments

Posttest Part 1 Questionnaire

Please answer all questions. Circle the correct answer where
appropriate. Guessing is permitted. If you do not know what the
answer is and do not wish to guess, write "DK" for don't know.

1.   Which helicopter type (types) is (are) based on the West ramp
at Hanchey Army Heliport?

2.   Which helicopter type (types) is (are) based on the East ramp
at Hanchey Army Heliport?

3.   In which compass orientation are the helicopters parked on
the West ramp at Hanchey? North-South orientation or East-West
orientation?

4.   In which compass orientation are the helicopters parked on
the East ramp at Hanchey? North-South orientation or East-West
orientation?

5.   How many helipads are located on the West ramp of Hanchey?

6.   How are these helipads identified or designated? (That is,
list the identification or designation of each of these
helipads.)

7.   Which traffic pattern is at a higher altitude? West Hanchey
traffic pattern or East Hanchey traffic pattern?

8.   How many windsocks are located at Hanchey?

9. Where is (are) the windsock(s) located relative the control tower? Use compass direction (i.e., North, South, East, West) to locate each windsock.

10. Where is the beacon tower located relative to the control tower? North, South, East, or West?

11. Where is the fire station located relative to the control tower? North, South, East, or West?

12. Where are the fuel tanks located relative to the control tower? North, South, East, or West?

13. How many fuel tanks are there?

14. What is the field elevation of Hanchey in feet?

Familiarization with Virtual Environments

Posttest Part 1 Object Placement Test

Use the generalized diagram of Hanchey Army Heliport provided. Place the following objects on the diagram in their correct locations. Guessing is permitted. If you do not know the answer and do not wish to guess, leave the question blank and go on. Please read through all questions first before answering any.

1.   Put a "WS" wherever a windsock is located.

2.   Put a "CT" where the control tower is located.

3.   Put a "BT" where the beacon tower is located.

4.   Label each helipad with its appropriate identifying designation.

5.   Put an "FT" where the fuel tanks are located.

6.   Put a "CH" where Cobra Hall is located.

7.   Put a "WCH" where the Windjammers Chinook Hall is located.

8.   Put an "HWC" where the Warrior Country hangar is located.

9.   Put an "H" where each of the other two hangars are located.

10.   Put an "FE" where each of the two field elevation signs are located.

11.   Put an "FS" where the fire station is located.

12.   Put the appropriate helicopter types, by name or alphanumeric designation, on the appropriate sides of the ramp.

Date_____   #_____

Familiarization with Virtual Environments

Posttest Part 2 Questionnaire

I am going to remove your goggles. Hold your head and eyes
steady and pointed forward. Do not turn your head to the left or
the right. Do not move from this spot. I am going to ask you
some questions. Please answer all questions. Guessing is
permitted. If you do not know an answer and do not wish to
guess, say "don't know."

a.   Do you see the "Warrior Country" logo?   Yes   No

1.   Where is the control tower located relative to your position?
To your front, back, left, or right?   DK

2.   Where is the fire station located relative to your position?
To your front, back, left, or right?   DK

3.   Which helicopter type or types are parked to your left?
AH-64 Apache   AH-1 Cobra   CH-47 Chinook   OH-58 Kiowa
UH-60 Blackhawk   UH-1 Huey   TH-67 Creek   RAH-66 Comanche
DK

4.   Which helicopter type or types are parked to your right?
AH-64 Apache   AH-1 Cobra   CH-47 Chinook   OH-58 Kiowa
UH-60 Blackhawk   UH-1 Huey   TH-67 Creek   RAH-66 Comanche
DK

5.   Where is Cobra Hall relative to your position?   To your
front, back, left, or right?   DK

6.   Where is the beacon tower relative to your position?   To your
front, back, left, or right?   DK

7.   Where is the antenna pole relative to your position?   To your
front, back, left, or right?   DK

8.   Where are the fuel tanks relative to your position? To your
front, back, left, or right?   DK

9.   Where is the water tank relative to your position? To your
front, back, left, or right?   DK

10.   Where is the nearest "field elevation" sign to your
position?   To your front, back, left, or right?   DK

11.   Where is taxi lane Delta relative to your position?   To your
front, back, left, or right?   DK

12.   Where is taxi lane Echo relative to your position?   To your
front, back, left, or right?   DK

13.   Which aircraft traffic pattern is at a higher altitude, the
traffic pattern to your left or the traffic pattern to your
right?   Left   Right   DK

14.   Relative to your position, is there a windsock:
      To your front?   Yes   No   DK
      To your back?   Yes   No   DK
      To your left?   Yes   No   DK
      To your right?   Yes   No   DK

15.   Where is Windjammers Chinook Hall relative to your position?
To your front, back, left, or right?   DK

16.   Where are the two silver natural gas tanks relative to your
position?   To your front, back, left, or right?   DK

17.   Where is the satellite receiver dish relative to your
position?   To your front, back, left, or right?   DK

Date_____   #_____

Familiarization with Virtual Environments

Hanchey Army Heliport Walking Navigation Test

PRACTICE WALK. [Starting Point: Warrior Country hangar reset
position] There are two field elevation signs on this heliport.
Please walk to and stand under the nearest field elevation sign.
Use the shortest route without passing through any buildings.
Do you understand? Yes No

Time_____   Wrong Turns_____

Judged Confidence Level_____
     1 = Unsure, looking, searching, halting steps
     2 = In between 1 and 3
     3 = Sure, confident, not searching, direct path

WALK 1. [Starting Point: Under field elevation sign on Warrior
Country hangar] Please walk to the two silver natural gas tanks,
passing on your way first the two blue port-a-potties then the
other field elevation sign. Use the shortest route without
passing through any buildings.
Do you understand? Yes No

Time_____   Wrong Turns_____

Judged Confidence Level_____
     1 = Unsure, looking, searching, halting steps
     2 = In between 1 and 3
     3 = Sure, confident, not searching, direct path

WALK 2. [Starting Point: Two silver natural gas tanks] Please
walk to the front of Cobra Hall, passing on your way first the
satellite receiver dish and then the entrance to Windjammers
Chinook Hall. Use the shortest route without passing through any
buildings.
Do you understand? Yes No

Time_____   Wrong Turns_____

Judged Confidence Level_____
     1 = Unsure, looking, searching, halting steps
     2 = In between 1 and 3
     3 = Sure, confident, not searching, direct path

Date_____   #_____

Familiarization with Virtual Environments

Hanchey Army Heliport Knowledge Rating Form

As a result of the self-guided exploration you performed in the
virtual Hanchey environment, how would you rate the level of
knowledge you gained about Hanchey Army Heliport? Please circle
a number from 1 to 5 below.

1	2	3	4	5
None	Some	Adequate	Much	Very Much

Where,
1 = None.   I learned nothing about Hanchey in the virtual
            environment.

3 = Adequate.   I learned enough in the virtual environment
                to find my way around Hanchey.

5 = Very Much.   I learned a great deal in the virtual
                 environment. I feel highly knowledgeable
                 about Hanchey now.

Date_____   #_____

PRESENCE QUESTIONNAIRE
Version 2.0, Bob Witmer & Michael J. Singer

Characterize your experience in the virtual environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer. ANSWER ALL QUESTIONS WITH REGARD TO THE VIRTUAL ENVIRONMENT.

1. How much were you able to control events?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|_____|_____|_____|_____|_____|_____|_____|
NOT   MODERATELY   COMPLETELY
RESPONSIVE   RESPONSIVE   RESPONSIVE

3. How natural did your interactions with the environment seem?

|_____|_____|_____|_____|_____|_____|_____|
EXTREMELY   BORDERLINE   COMPLETELY
ARTIFICIAL   NATURAL

4. How completely were all of your senses engaged?

|_____|_____|_____|_____|_____|_____|_____|
NOT   MILDLY   COMPLETELY
ENGAGED   ENGAGED   ENGAGED

5. How much did the visual aspects of the environment involve you?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

6. How much did the auditory aspects of the environment involve you?

|____|____|____|____|____|____|____|____|
NOT AT ALL   SOMEWHAT   COMPLETELY

7. How natural was the mechanism which controlled movement through the environment?

|____|____|____|____|____|____|____|____|
EXTREMELY   BORDERLINE   COMPLETELY
ARTIFICIAL   NATURAL

8. How aware were you of events occurring in the real world around you?

|____|____|____|____|____|____|____|____|
NOT AWARE   MILDLY   VERY AWARE
AT ALL   AWARE

9. How aware were you of your display and control devices?

|____|____|____|____|____|____|____|____|
NOT AWARE   MILDLY   VERY AWARE
AT ALL   AWARE

10. How compelling was your sense of objects moving through space?

|____|____|____|____|____|____|____|____|
NOT AT ALL   MODERATELY   VERY
                          COMPELLING   COMPELLING

11. How inconsistent or disconnected was the information coming from your various senses?

|____|____|____|____|____|____|____|____|
NOT AT ALL   SOMEWHAT   VERY
INCONSISTENT   INCONSISTENT   INCONSISTENT

12. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|____|____|____|____|____|____|____|____|
NOT   MODERATELY   VERY
CONSISTENT   CONSISTENT   CONSISTENT

13. Were you able to anticipate what would happen next in response to the actions that you performed?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

14. How completely were you able to actively survey or search the environment using vision?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

15. How well could you identify sounds?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

16. How well could you localize sounds?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

17. How well could you actively survey or search the virtual environment using touch?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

18. How compelling was your sense of moving around inside the virtual environment?

|_____|_____|_____|_____|_____|_____|_____|
NOT   MODERATELY   VERY
COMPELLING   COMPELLING   COMPELLING

19. How closely were you able to examine objects?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   PRETTY   VERY
                            CLOSELY   CLOSELY

20. How well could you examine objects from multiple viewpoints?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   EXTENSIVELY

21. How well could you move or manipulate objects in the virtual environment?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   EXTENSIVELY

22. To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   MILDLY   VERY
                                DISORIENTED   DISORIENTED

23. How involved were you in the virtual environment experience?

|_____|_____|_____|_____|_____|_____|_____|
NOT   MILDLY   COMPLETELY
INVOLVED   INVOLVED   ENGROSSED

24. How distracting was the control mechanism?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   MILDLY   VERY
                                DISTRACTING   DISTRACTING

25. How much delay did you experience between your actions and expected outcomes?

|_____|_____|_____|_____|_____|_____|_____|
NO DELAYS   MODERATE   LONG
                                  DELAYS   DELAYS

26. How quickly did you adjust to the virtual environment experience?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SLOWLY   LESS THAN
                                                             ONE MINUTE

27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|_____|_____|_____|_____|_____|_____|_____|
NOT   REASONABLY   VERY
PROFICIENT   PROFICIENT   PROFICIENT

A-22

28. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   INTERFERED   PREVENTED
                           SOMEWHAT   PERFORMANCE

29. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   INTERFERED   INTERFERED
                           SOMEWHAT   GREATLY

30. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY

31. Did you learn new techniques that enabled you to improve your performance?

|_____|_____|_____|_____|_____|_____|_____|
NO   LEARNED   LEARNED
TECHNIQUES   SOME   MANY
LEARNED   TECHNIQUES   TECHNIQUES

32. Were you involved in the experimental task to the extent that you lost track of time?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL   SOMEWHAT   COMPLETELY